‘Acceleration of the Transition to a Sustainable and Renewable Energy Future in Mexico through Clean Energy Certificates’

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The candidate confirms that the work submitted is his own and that appropriate credit has been given where reference has been made to the work of others.

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Abstract

Currently, there is a constant commitment of governments around the world for reducing the emissions of pollutants and mitigate the effects of the climate change through the deployment of renewable energy for electricity generation. Governments have adopted policies and targets for fostering the use of clean technologies in order to be cost-competitive with fossil fuels technologies.

The clean energy certificate markets have been created by the governments as an incentive for integrating the participation of renewable energies into their energy portfolios. In 2013, Mexico enacted an Energy Reform with the purpose to oversight a gradual participation of renewable energies in the electricity industry with a renewable target of 35% as a minimum in electricity generation from clean energy sources by 2024. In 2018, a clean energy certificate market will be launched by the Mexican government in order to accelerate the pace to reach the renewable energy target.

This research project outlined the need for identifying best global practices in the design features of clean energy certificate markets through the analytical method of the socio-technical system approach for the Mexican clean energy certificate market to accelerate the transition to a sustainable energy in Mexico.

The aim of this research project is to evaluate the countries with high penetration of renewable energies through the implementation of a clean energy certificate market. It is worth noting that the evaluations of the countries are presented as follows: Sweden and Norway, United Kingdom, Australia, India and the state of California in the United States.

The research project highlights the findings of the best international practices and failures as result of the evaluations made with the socio-technical system approach and the recommendations for the Mexican clean energy certificate market.

Contents

List of Figures

List of Tables

List of Abbreviations

CEC	Clean Energy Certificate
CERC	Central Electricity Regulatory Commission
CfD	Contract for Difference
CHP	Combined Heat and Power
CRE	Comision Reguladora de Energia (Energy Regulatory Commission)
CSI	California Solar Initiative
EMR	Electricity Market Reform
FIT	Feed-in tariff
GDP	Gross Domestic Product
GWh	Gigawatt-hour
IEA	International Energy Agency
IEX	Indian Energy Exchange Limited
IRENA	International Renewable Energy Agency
kWh	Kilowatt-hour
LRET	Large-scale Renewable Energy Target
MRET	Mandatory Renewable Energy Target
MTOE	Million Tonnes of Oil Equivalent
MWh	Megawatt-hour
NAPCC	National Action Plan for Climate Change
NFPA	Non-Fossil Purchasing Agency
NLDC	National Load Despatch Centre
OFGEM	Office of Gas and Electricity Markets
PV	Photovoltaic
PXIL	Power Exchange India Limited
RD&D	Research, Development and Demonstration
RES	Renewable Energy Sources
ROC	Renewable Obligation Certificate
RPO	Renewable Purchase Obligation
SERC	State Electricity Regulatory Commission
SRES	Small-scale Renewable Energy Scheme
SST	System Scenarios Tool
TWh	Terawatt-hour
WREGIS	Western Renewable Energy Generation Information System

1 Introduction

1.1 Global energy outlook

In 2016, the world energy consumption was estimated in 13,276.3 MTOE (million tonnes of oil equivalent). Indeed, oil is still the dominant global fuel of the total consumption since 1999, followed by coal and natural gas, resulting from this, a fossil fuel provision of 86% of total consumption. Moreover, renewable energies have a 10% of participation in energy supplied, and nuclear energy on a minimum scale with 4% (BP 2017a). The increasing worldwide interest on energy generation and distribution from a sustainable approach with low prejudicial repercussions for human health with a reduction of air pollution and climate change mitigation in terms of greenhouse gases, acid precipitation, and stratospheric ozone depletion (Alemán-Nava *et al.* 2014). Furthermore, the need for heighten the use of renewables energies sources for energy supply in order to reduce the demand for oil, coal and natural gas, alongside the socio-economic benefits such as the development of clean technologies, infrastructure improvement, support for sustainable projects, poverty reduction etc. These benefits play an important role in economic and welfare growth with increasing job opportunities, as well as, the interaction of markets and investors (IRENA 2016).

The British Petroleum Company (BP 2017b) considers renewable energies as those energies generated from natural procedures that do not include the utilisation of exhaustible resources, mainly fossil fuels and uranium. This implies that renewable energies encompass hydroelectricity, wind, wave power, solar, geothermal energy and combustible renewables and renewable waste (landfill gas, waste incineration, strong biomass and fluid biofuels). Likewise, governments adopt policies and targets to deploy the use of renewable energy sources, in accordance with the natural resources available and specific economic conditions (BP 2017b).

1.2 Renewable Energy Incentives

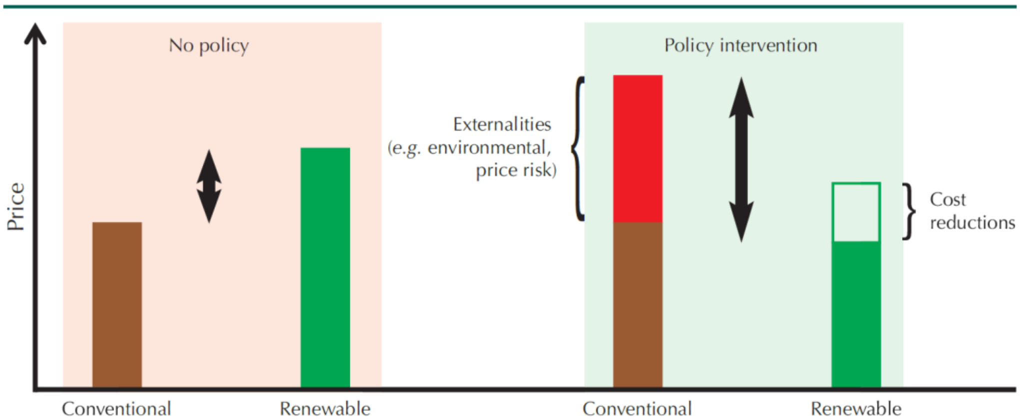
Countries around the world have an important participation in the integration of renewable energy sources into their energy portfolios. The fossil fuels reliance is the first issue to tackle and reduce exposure to the volatility of fuel price through the rise of renewable energy capacity and infrastructure (Carley *et al.* 2017). Likewise, the process of energy generation from renewables produces a minimum quantity of pollutants in comparison to fossil fuels sources that produce large quantities of greenhouse gases and carbon dioxide. Consequently, countries have defined approaches for fostering the renewable energy technologies (Wang, Gong and Jiang 2014).

The investment of governments in renewable energies has provoked a positive rise in the climate policies momentum as result of the Paris Agreement. These policies are needed for achieving the targets of economic growth, environmental sustainability and energy security. Governments have paid attention to the economic benefits that the investments in clean technologies generate through the reduction of negative side effects and guarantying the social and employment benefits. Thus, the climate policies momentum is primordial for keeping the transition to renewable energies (IEA 2017n).

The governments have to use diverse strategies to make profitable a renewable energy market in terms of a reduction in the installation cost of renewable energy projects. These strategies are designed to improve the financial viability and decrease the cost of energy production (Thapar, Sharma and Verma 2016). In most cases, the strategies implemented by the governments for renewable energy deployment are a short and long-term strategies combination. Nevertheless, long-term strategies are more relevant for creating a new type of generation and energy uptake (Aquila *et al.* 2017).

A financial assessment by the government is an essential factor to deploy the use of renewable energy, which needs to have an extra support in order to be competitive with fossil fuels technologies (Abolhosseini and Heshmati 2014). An economic barrier is imposed owing to clean technologies are not commonly competitive on cost in the current energy generation mechanisms. However, the development of renewable energies has represented a cost reduction in crucial technologies, becoming cost-competitive and reducing the need for a financial support. But, in the case of newer renewable technologies, economic support is needed to provide a deployment at lower cost and in a larger scale in the future (Figure 1. 1) (IEA 2011a). Currently, there are mechanisms to foster the renewable energy capacity through financial support, the most widely employed mechanisms are the feed-in tariffs, tax incentives and clean energy certificates (Abolhosseini and Heshmati 2014).

Figure 1. 1: Factors influencing RE competitiveness and the role of policies



Source: (IEA 2011a)

The effort of the governments has increased throughout the last years. It can be translated in the constant growth in renewable energy generation through the implementation of incentives. Globally, the electricity generated from renewable energies had a rise of 6% in 2016 in comparison to the previous year. This electricity represented nearly 24% of the total electricity generated worldwide. The largest renewable source was hydropower with approximately 70%, wind accounting for 16%, followed by bioenergy 9% and solar PV 5% (IEA 2017j).

However, there is a risk of not reach the long-term renewable targets for electricity generation only with the widespread of onshore wind and solar PV. The main challenges that government face is the design of the renewable policies. These policies have to provide a greater revenue certainty, an improved infrastructure grid for the renewables integration and reduce the cost of financing for developing countries (IEA 2017j).

1.2.1 Feed-in tariffs

Feed-in tariffs (FITs) is the most used mechanism by countries in the world, where a price is set for sale per kWh of electricity produced from renewable sources, this price is determined for a period of around 20 years. During this period of time, the tariff has to be amended based on the inflation, it applies only to new generation plants (IEA 2011b).

There are included three features in feed-in tariffs: the grid access must be guaranteed, a long-term stability through 15-20 years contracts and the price paid for electricity produced reflects the real cost of renewable energy generation (Nicolini and Tavoni 2017). In the feed-in tariff scheme is also involved a premium on top payment for electricity generators, this premium is previously determined and has a variation depending on the electricity market price. In some cases, the governments set an annual price cap on the electricity generation quantity (IEA 2011b).

1.2.2 Tax incentives

Typically, tax credits are applied to investment, production or consumption of renewable electricity generation. The implementation of tax policies can help to decrease the uptake of fossil fuels, for instance, a carbon tax for using fossil fuels promotes the rise of renewable energy technologies for electricity production. Tax incentives also encompass subsidies and tax deductions to motivate the use of energy from renewable sources, rising the importance in reducing the negative consequences for environment (Abolhosseini and Heshmati 2014).

Tax incentives are designed to be an attractive and profitable opportunity for private individuals and companies to make investments in renewable energy projects. The effectivity of tax incentives can be compared equally to a subsidy of around 25% to 35% on the investments made by companies (Abdmouleh, Alammari and Gastli 2015). Tax incentives are also applied to renewable energy equipment and appliances, where the banks play a very important role in order to attract and ease the investments in green technologies for all participants. This mechanism recompenses the renewable energy technology investments and creates a higher level of attention for the involved parties (Ecotec 2001).

1.2.3 Clean energy certificates

This instrument is based on an obligation quota for renewable energy generation set by the government to electricity generators. As a result, a clean energy certificate market is created for energy suppliers, and the certificate price is determined by supply and demand. Therefore, the electricity producers have a quota obligation to fulfil from renewable energy sources through presenting or buying clean energy certificates for obligation compliance. The options for electricity generators to receive certificates are: from self-electricity production from renewable sources or buying clean energy certificates in the market (Nicolini and Tavoni 2017). In case of a non-fulfilment obligation quota by the electricity generator, a penalty fee is allocated. The original design of the certificates had the same value for any renewable technology, later, it was modified to create a more competitive certificate market among renewable technologies (IEA 2011b).

1.3 Renewable energy in Mexico

Recently, the Mexican government has been looking for the progress of energy sustainability in order to include a cleaner environment as one of the key elements of competition that supports the economic growth and social development of the population. Therefore, there is a clear commitment, drawn in the Energy Reform (Reforma Energética) that government enacted in 2013 (Mexico 2014): to oversight a gradual participation of renewable energies in the electricity industry, in terms of meeting the established goals in the matter of clean energy generation and emissions reduction (SENER 2016b).

The general purpose of the Energy Reform is to establish an energy sector more sustainable, practical, effective, straightforward, and beneficial to extend the advantages drawn from the nation's hydrocarbon resource, likewise fostering the use the low-carbon sources. This implies that Mexican policies are translated into the climate change mitigation, in the same way, Mexico was the second country to enshrine its climate change targets into law and has been characterised throughout history by the commitment to address environmental concerns that have been taken seriously on the COP21 2015 meeting in Paris, showing a great interest and strong decision in a climate change pledge, which is focused in decrease by 25% and by up to 40% of greenhouse-gas emissions and short-lived climate pollutant emissions according to a compulsory economy-wide aim by 2030 with access included to low-cost financial resources and technology exchange, that are considered under a variety of factors (IEA 2016).

The costs reduction, especially for solar and wind energy, has allowed a considerable increase in the participation of renewable energies as sources of clean energy generation, along with the support policies for renewable energies in Mexico, derived from the Energy Reform, have contributed to the strengthening of the energy market by making renewable energy highly competitive with conventional fuels in the electricity sector. The chance to identify areas with high potential for renewable energies allows developers and stakeholders to invest in projects that contribute to the diversification of the energy industry (Table 1. 1) (SENER 2016b).

Table 1. 1: Electricity Generation Potential from Clean Energies in Mexico (2015) (GWh)

Resources	Wind	Solar	Hydropower	Geothermal	Bioenergy
Proven	19,805.00	16,351.00	4,796.00	2,355.00	2,396.00
Probable	-	-	23,028.00	45,207.00	391.00
Possible	87,600.00	6,500,000.00	44,180.00	52,013.00	11,485.00

Source: (SENER 2016b)

Mexico is committed to complying the mitigation aims set in the Energy Transition Law, which states that the electricity sector must be transformed with a minimum electricity generation of 35% by 2024, 40% by 2035 and 50% by 2050 from clean energy sources. In order to meet these targets, a clean energy certificate market will be launched in 2018 (IEA 2017a).

1.4 CEC market in Mexico

In the National Development Plan 2013-2018, the National Goal ‘Mexico Prosperous’, sets an objective to supply energy to the country with competitive prices, quality and efficiency along the productive chain, for strengthen the supply from renewable sources through the adoption of new technologies and international best practices in the matter, which include the establishment of clear rules that encourage the development of a competitive market. The clean energy certificate market is an instrument to promote new investments in clean energies and allow to transform in national obligations the national goals of clean generation of electricity, in an efficient way and at the lowest cost for the country, hence, the clean energy certificate market will be launched in 2018 (SENER 2014).

The Ministry of Energy (SENER) has defined a target for minimum electricity production from renewable sources of 28.3% or 90.5 TWh by 2020 (SENER 2017b), 35% by 2024 and 50% by 2050; these targets are set in the Energy Transition Law (SENER 2017a). Therefore, the electricity producers established after August 11th 2014 or the existing plants who add electricity capacity production from renewables, and volunteer entities can receive clean energy certificates for over a maximum of 20 years (SENER 2014).

The renewable purchase obligation has been determined by the Ministry of Energy in 5.0% for 2018 (SENER 2015b), 5.8% for 2019 (SENER 2016a), 7.4% for 2020, 10.9% for 2021 and 13.9% for 2022 (SENER 2017b). The certificates will be surrender in the Certificate Management and Clean Energy Compliance System (Sistema de Gestión de Certificados y Cumplimiento de Obligaciones de Energias Limpias, S-CEL). This monitoring system will register the certificate operations and the renewable purchase obligation compliance (CRE 2016a), under supervision of the Energy Regulatory Commission (Comisión Reguladora de Energía, CRE), who is the regulatory authority that issues and regulates the requirements for the clean energy certificates, verifies the obligation compliance of the clean energy certificate market participants, and promotes the electricity generation from renewable sources (SEGOB 2014).

The price of the clean energy certificates is determined by supply and demand and is regulated by the National Centre for Energy Control (CENACE). The first price of clean energy certificate for 2018 has been set in $24.30 USD, this price is equal to the 90% of the lowest penalty fee (SENER 2015a). The clean energy certificate market has been designed under a technology-neutral scheme and the renewable energy technologies eligible for receiving certificates are wind, solar, hydropower, nuclear, bioenergy power, wave power and geothermal energy (SEGOB 2014).

The Energy Regulatory Commission will issue one clean energy certificate for each megawatt-hour (MWh) generated from eligible renewable sources, and the clean energy certificates have a shelf life until they will be cancelled (SENER 2014). However, the sunset clause of the clean energy certificate market has not been defined by the Mexican government. Lastly, the Mexican penalty fee is calculated for each megawatt-hour a shortfall in the renewable purchase obligation by the obligated entities from $27

USD to $189 USD. It will be determined if it is a non-deferred or deferred obligation, shortfall percentage, and the obligation incidence (Table 1. 2) (CRE 2016b).

Table 1. 2: Matrix for penalty fee calculation in USD

	Non-deferred obligation				Deferred obligation			
Shortfall percentage	**0%-25%**	**25%-50%**	**50%-75%**	**75%-100%**	**0%-25%**	**25%-50%**	**50%-75%**	**75%-100%**
First Time	27	36	45	54	36	45	54	63
Second Time	54	72	90	108	72	90	108	126
Third Time	81	108	135	162	108	135	162	189

Source: *(CRE 2016b)*

1.5 Research scope

The purpose of this research project is to analyse the experience gained and lessons learnt from international clean energy certificate markets design, through the application of an analytical framework, in order to identify the best practices for the Mexican clean energy certificate market to accelerate the transition to a sustainable energy in Mexico.

1.5.1 Aim

Evaluate the international best practices of the current clean energy certificate markets, identify the mechanisms to boost the clean energy certificate market of Mexico and provide practical guidance to deploy the use of renewable energy through the clean energy certificate market in Mexico.

1.5.2 Objectives

- Analyse the best practices and experience gained of leader countries with the implementation of a clean energy certificate market.
- Make an assessment of the current clean energy certificate market design of Mexico.
- Identify the gaps in the Mexican clean energy certificate market design.
- Aim to provide technical guidance for aid the deployment of renewable energies in Mexico through the clean energy certificate market.

2 Literature review

2.1 Need for identify best practices

The lack of an analytical method for identifying best global practices in the design features of clean energy certificate markets has outlined the need for a methodological tool to be applied for research. This analytical method has to be able to include the economic, market and scientific factors, as well as institutional, cultural and social factors (Smith, Voß and Grin 2010) based on the robust and diverse experience of countries that have already had important progress in the integration of renewable energies sources in their electricity generation share.

This analytical method has to address the best practices obtained from global clean energy certificates markets for the implementation of new markets or amended of existing markets, in order to promote and deploy the use of renewable energy in electricity generation.

It is important however not to assume the applicability of this analytical method in all cases. Each country accounts with unique characteristics in terms of technical needs, resources available, institution and human involving, regulations and policies that have to be considered for identifying the best practices.

2.2 Institutions involvement

As outlined in the previous chapter the importance and reasons of why the government support is needed for the deployment of renewable energy technologies in the electricity generation. Governmental institutions play a fundamental role for meeting the renewable targets. In particular, governmental institutions are involved for enforcing and regulating the renewable energy generation markets within the governmental structure of the countries.

Since 1990's, energy institutions have evolved significantly, thereby the institutions or regulatory agencies were created under a new independent scheme. This scheme introduced the electricity markets competitiveness in most countries (Fulbright 2017). The institutional efforts in the deployment of renewable energy are interconnected with the economic, political, socio-cultural, financial and technical factors. Together, these factors work to overcome the challenges that countries face in meeting the renewable targets (REN21 2017).

An essential function of the institutions is being the connection between government and enterprises for reaching energy end users and make the transition to a widespread use of renewable sources (IEA 2017o).

2.3 Renewable technology competitiveness

The technology progress throughout the years has been driven by the energy efficiency improvements. It has made possible the deployment of new best renewable energy technologies (Transitions 2017). Whereas the renewable energy sector and technologies mature, become more competitive (GWEC 2016a).

Also, the government contributes to the competitiveness of the clean technologies through the investments. These investments are translated into subsidies for the energy generated from renewable sources (IRENA 2016). In 2016, the total investment support in the world for renewable energy amounted to USD 297 billion (IEA 2017n). From the perspective of enterprise, these investments make the renewable technologies competitive in cost with fossil fuels.

2.4 Social support of RES

The social acceptance in the use of renewable technologies for electricity generation is an issue that can help to tackle the challenges and barriers in the adoption of climate mitigation goals. In particular, the International Energy Agency (IEA 2011a) highlights the social acceptance as a critical issue for some technologies in terms of regulatory and policy uncertainty when economic barriers are eliminated.

Huesca-Pérez, Sheinbaum-Pardo and Köppel (2016) classify four different factors in social impacts of renewable energy: socio-economic, socio-cultural, socio-environmental and stakeholder’s involvement. Consequently, the reduction of social impacts can be made through guidelines for best practices, institutional involvement and regulation.

2.5 CEC market design

The design of a clean energy certificate market of each country reflects the insights to overcome the deployment of renewable technologies, according to geography, market and power system. A one-size-fits-all approach does not exist, each country has an own market design to create a successful renewable integration (NREL 2012).

However, many elements are considered by policymakers in the designing process of a clean energy certificate market. The mainly features involved in the design of this renewable electricity scheme support are (Xin-gang *et al.* 2014):

-Renewable purchase obligation setting: a minimum percentage of renewable energy generation has to be set by the government, preferentially, this obligation has to enact by law in order to create certainty for investors and has to rise over the time.

-Eligible renewable technologies: in accordance with the natural resources available in each country, governments choose the eligible renewable energy technologies to participate in the certificate market.

-Obligated entities: the definition of the obligated entities for the renewable generation with the actors involved in the electricity market is very important due to the existing organisation in the countries.

-Certificate design: the amount of electricity generated from eligible renewable technologies for each certificate issued, this amount can be different from country to country. Also, the information contained in the clean certificate can describe the production date or the renewable technology source.

-Penalty scheme: the design of the penalty scheme is fundamental for the renewable purchase obligation compliance. The penalty fee has to be higher than the certificate price in order to fulfil with the main obligation quota. The amount collected from the penalty fees can be applied for a fund to strengthen the clean technologies capacity.

-Organisation of the market: the information of the certificate price and performance of the clean energy certificate market amongst stakeholder is necessary for risk reduction and profits improvement. A monitoring system or trading platform is indispensable for the market well-being.

-Institutions involved: the regulatory authorities of the clean energy certificate market are defined for organising, managing and supervising the certificate operations.

2.5.1 Pros of CEC's

Globally, the clean energy certificate support mechanism has been implemented at the national level in 26 countries and in addition, in 72 states or provinces (Wędzik, Siewierski and Szypowski 2017). Also, it can be implemented in small electricity markets or in countries where one electricity generator monopolises the market (Abdmouleh, Alammari and Gastli 2015).

The implementation of a clean energy certificate market offers effectiveness in promoting renewable energy generation with a dynamic efficiency and low cost in transactions, preventing windfall profits (Ragwitz, del Río González and Resch 2009). The design of this support scheme allows for renewable energy production be certified in order to prove the meeting of renewable energy generation targets to stakeholders (G.J. Schaeffer 1999).

Aune, Dalen and Hagem (2012) have indicated in a numerical model that the implementation of a clean energy certificate market may reduce the total cost of renewable energy target achievement up to 70% in comparison with an absence of this support mechanism. This cost reduction impacts on the government financing in the distribution of renewable electricity in a more cost-effective manner for reaching the renewable targets. Indeed, this reduction in cost depends on the design of the clean energy certificate market of each country.

The clean energy certificate markets are characterised by the high compatibility with market principles and the competitive price determination (ECOFYS 2014). This market allows the competence amongst the renewable energy generators due to the price of certificates depends on supply and demand of clean energy certificates (Abdmouleh, Alammari and Gastli 2015).

Worldwide, the main support systems in the renewable electricity generation employed by governments are clean energy certificates and the feed-in tariffs (Wędzik, Siewierski and Szypowski 2017). Therefore, it is worth noting that the clean energy certificate system offers a wide regulation for developing renewable capacity and is cheaper in terms of public finances than the feed-in tariff system. This implies that the clean energy certificate system addresses the high upfront costs of clean technologies, stabilises the electricity prices and motives the competition in the direct price between power plants (Nicolini and Tavoni 2017).

Contrary to the feed-in tariff system that the government is obligated to buy the renewable energy generated, the clean energy certificate system is based on the private market for its operation, it follows that it is related to producers instead of end users. This reflects that the clean energy certificate market has an enhanced performance of cost-efficiency than the feed-in tariff system. Consequently, the implementation of a feed-in tariff system is applied when a low-risk investment exists for deploying renewable energy technologies and the certificate system is applied when the government implements a policy based on a wide market vision (Abolhosseini and Heshmati 2014). Tamás, Bade Shrestha and Zhou (2010) analysed data from a clean energy certificate market and feed-in tariff scheme, finding a higher social welfare in the former than the latter.

2.5.2 Cons of CEC's

Wang, Gong and Jiang (2014) argue that the clean energy certificate support mechanism aids to deploy renewable technologies in a low cost, while the promotion for new technologies is lesser. This implies that the clean energy certificate system presents weaknesses in the deployment of new renewable technologies. Thus, quota obligation defined by the governments is outlined in a technology-neutral scheme, where are benefited only the most cost-effective technologies. As a result of this, the renewable targets are reached at the lowest cost in a short-term, but not for the long-term owing to the minor support for the most cost-intensive technologies. Consequently, windfall profits usually occur for the lower cost technologies (ECOFYS 2014).

A frequent problem in the clean energy certificate market implementation is the certificate price fluctuation, provoking a negative impact on renewable energy investments. A certificates shortfall in the market increases price very high; on the contrary, a certificates surplus decreases price very low. This volatility in the certificate price is due to a deficiency of liquidity and a limitation in the support mechanism of the market (Verhaegen, Meeus and Belmans 2009).

As mentioned above, on contrary sense, a certificate price fluctuation is created by a rise on renewable energy investments, when the amount of issued certificates by energy producers is greater than the purchased certificates, leading to a decrease in the certificates price (Pavaloaia, Georgescu and Georgescu 2015).

An instability in the certificate prices causes high-risk premiums that increase the policy cost. Occasionally, auto-regulations for certificates prices have to be set in order to avoid drops in prices once renewable targets are met. The income stream of energy producers is affected by these price drops and create an increment in risk premiums. Hence, a “headroom” is adapted to the quota target to avoid price drops, but this adaptation may affect the accuracy of the target reaching (ECOFYS 2014).

2.6 Socio-technical system

2.6.1 Introduction to socio-technical system review

The examination of the socio-technical system approach and its importance as an analytical method to be applied to evaluate the performance of the global clean energy electricity markets. In the same manner, a critical review of the socio-technical components that integrate the connections amongst the stakeholders. Lastly, outline the strengths and weaknesses of the socio-technical system approach.

2.6.2 Socio-technical systems design

After World War II, the socio-technical system concept appeared, in work performed by what is now named Tavistock Institute (Mumford 2006). They realised that the employees of a mining company did not work in specialised and divided activities. The social aspect played an important role in the use of technologies by individuals

(University of St Andrews 2012). Tavistock Institute focused on the whole organisation defined as an “open socio-technical system” (Klein 2014).

Socio-technical systems design is an approach that considers human, social, organisational and technical factors in the organisational systems design. The understanding of how affects the human, social and organisational factors in the performance of work and the application of technical systems (Baxter and Sommerville 2011).

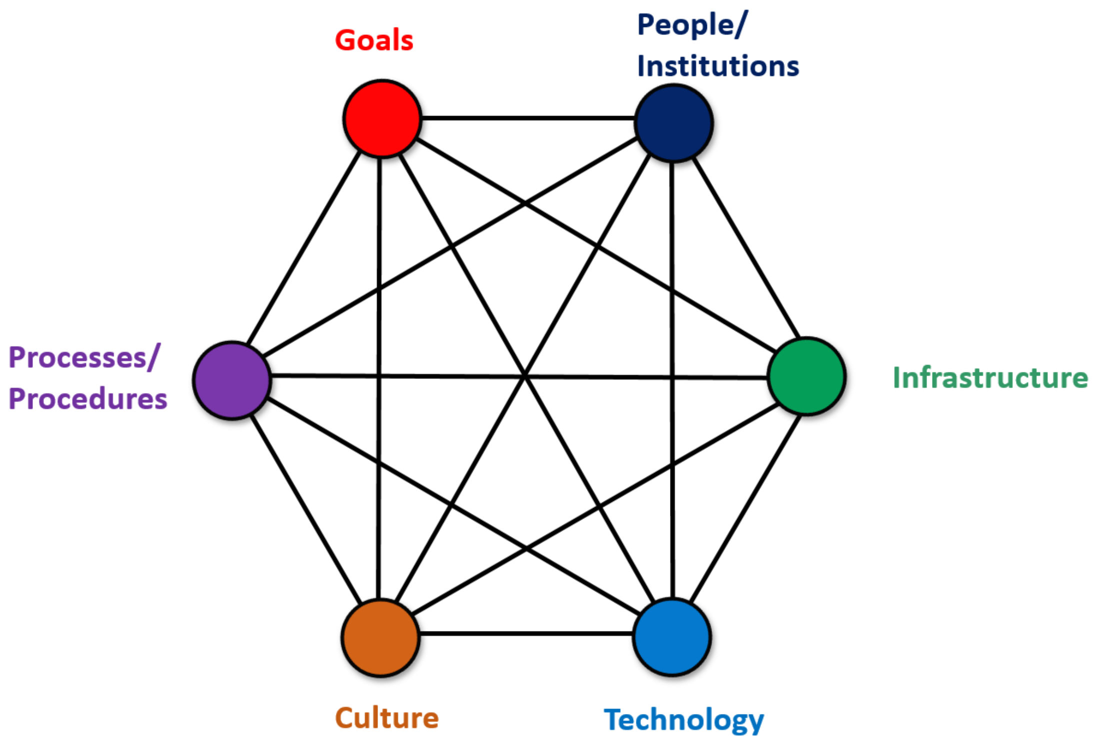
New technologies evolve alongside their functions, in accordance with the arising of needs. Technological practices have to be under assessment in terms to find the best way to be enhanced. The socio-technical system works with stable settings of institutions, procedures, practices, norms, and networks that define an ordinary development and technologies application (Smith, Stirling and Berkhout 2005).

Socio-technical system approach outlines the interdependence of technology and people in a working system. Technology influences the performance of people, and the performance of people influences the functioning of technology. Hence they both have to consider how they influence each other (Klein 2014). A primary concern of the socio-technical system approach made by Geels (2002) is to describe and illustrate a conceptual perspective for a transition from evolutionary economics and technology learnings. Foxon (2011) proposes the development of a coevolutionary framework through the analysis of a transition from the perspective of ecosystems, institutions, user practices, business strategies and technologies.

2.6.3 Socio-technical framework

A socio-technical framework has been chosen for this research project based on the original schema made by Leavitt (1965) and later adjusted by other users. This framework was basically focused on the interdependence amongst people, tasks, structures and technologies. Subsequently, an extended framework was amended by Challenger and Clegg (2011) (Figure 2. 1). This socio-technical framework provides an analysis of the interrelation of goals and metrics, engage people (including different skills and attitudes), applying a range of technology and tools, employing a physical infrastructure, performing with cultural suppositions, and managing sets of processes and practices. This method is practical in the application of core ideas to reach new fields and go further than the traditional central point on new technologies and simultaneously become engage in predictive work by making important contributions (Davis *et al.* 2014).

Figure 2. 1: Socio-Technical Systems Theory



Source: (Challenger and Clegg 2011)

2.6.4 Socio-technical system domains and applications

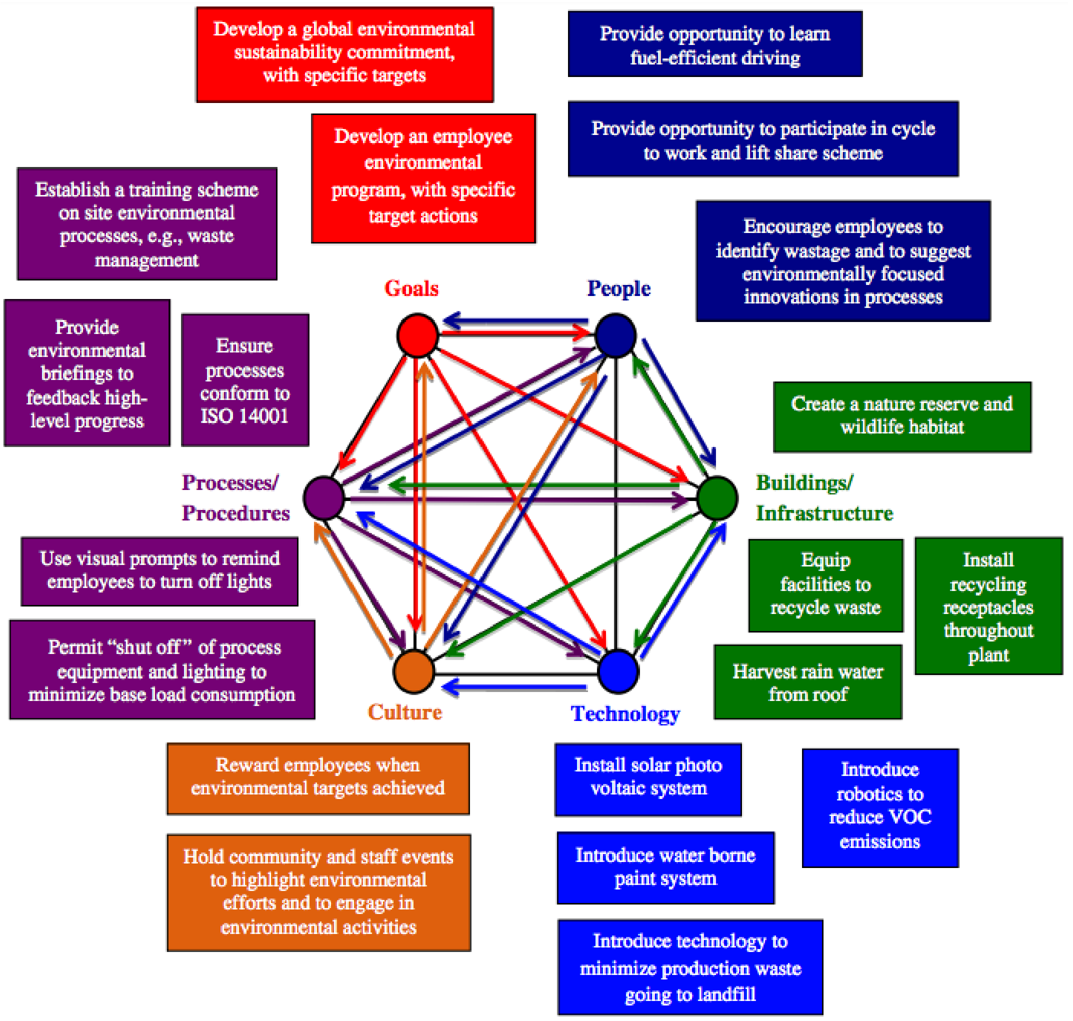
The main application of the socio-technical theory focuses on the design and performance of any structural entity. This implies that it can be used within a multi-level perspective at the micro-meso-macro level (Foxon 2011). The socio-technical theory can be identified and enhanced under a social and technical context, and make them work together as related parts of a compound system. The socio-technical thinking framework can be applied to both part of an organisation or a whole organisation, and interact with sub-systems, where people are employed with specific skills to reach the organisation goals, in accordance with the process or procedures previously established, making use of technology, performing operations within a physical infrastructure, having in common a certain cultural ideas and rules (Leeds 2017).

A wide conceptualisation regarding the performance of the systems acquired by the people involved with the socio-technical thinking, allow the application of fundamental ideas to new domains, further than regular ideas through new technologies. The principles and philosophy of the socio-technical thinking have been used positively in varied fields of knowledge, being most popular its application in new technologies design and task assignation redesign (Davis *et al.* 2014).

Hughes *et al.* (2017) have outlined a recent and useful methodology to design or re-design working systems that can be operated by designers, end-users, consultants or researchers, this methodological tool is called “System Scenarios Tool” (SST), which involves stakeholders, system parameters, data collection, analysis and an action plan.

The socio-technical system approach has been applied in a variety of fields. Davis *et al.* (2014) identify the socio-technical factors involved supporting entities to enhance their environmental sustainability (Figure 2. 2). The objective of this work is to develop theory and guide to report a future procedure in order to avoid these kinds of catastrophic events.

Figure 2. 2: Approaches and initiatives implemented to support greater environmental sustainability at a major UK manufacturing plant



Source: (Davis et al. 2014)

The summary of the key interdependent factors involved in the analysis made to the components: culture, goals, infrastructure, technology, processes and procedures, and people through the socio-technical system approach is found below (Table 2. 1).

Table 2. 1: Summary of the interrelated factors underpinning the environmental sustainability at the UK plant

Key Socio-Technical Factors	Environmental Sustainability
Goals	Develop a global environmental sustainability commitment, with specific targets
	Develop an employee environmental program, with specific target actions
People	Provide opportunity to learn fuel-efficient driving
	Provide opportunity to participate in cycle to work and lift share scheme
	Encourage employees to identify wastage and to suggest environmentally focused innovations in processes
Buildings/ Infrastructure	Create a nature reserve and wildlife habitat
	Equip facilities to recycle waste
	Install recycling receptacles throughout plant
	Harvest rain water from roof
Technology	Install solar photo voltaic system
	Introduce water borne paint system
	Introduce robotics to reduce VOC emissions
	Introduce technology to minimize production waste going to landfill
Culture	Reward employees when environmental targets achieved
	Hold community and staff events to highlight environmental efforts and to engage in environmental activities
Processes/ Procedures	Establish a training scheme on site environmental processes, e.g., waste management
	Provide environmental briefings to feedback high-level progress
	Ensure processes conform to ISO 14001
	Use visual prompts to remind employees to turn off lights
	Permit “shut off” of process equipment and lighting to minimize base load consumption

Source: (Davis et al. 2014)

2.6.5 Principles of socio-technical systems design

The socio-technical system design is underpinned by principles that allow a consistent structure for assessment aims. These principles have fundamental purposes that highlight the gaps of design and designers in order to be corrected. They emphasise the perceptions amongst connections in the system design, such as taking into consideration the participation of end-users in the development of the design, tasks assignation, data framework and the outlined jobs. These perceptions are related to content and process problems (Clegg 2000).

According to the socio-technical system, the design and operation of a system are underlying to improve the social and technical factors within an organisation. The connections of the components of the clean energy certificate market are based on the socio-technical system design (Table 2. 2) and the interrelated principles. These principles have four essential capacities: feature issues in specific considerations in the design process; to emphasise the need for a progression of connected viewpoints on design; to give a perspective configuration for systems analysis, and to provide projections about future systems operation (Challenger and Clegg 2011).

Table 2. 2: Principles of socio-technical systems design

Meta-principles
1.- Design is systemic
2.- Values and mindsets are central to design
3.- Design involves making choices
4.- Design should reflect the needs of the business, its users and their managers
5.- Design is an extended social process
6.- Design is socially shaped
7.- Design is contingent
Content principles
8.- Core processes should be integrated
9.- Design entails multiple task allocations between and amongst humans and machines
10.- System components should be congruent
11.- Systems should be simple in design and make problems visible
12.- Problems should be controlled at source
13.- The means of undertaking tasks should be flexibly specified
Process principles
14.- Design practice is itself a socio-technical system
15.- Systems and their design should be owned by their managers and users
16.- Evaluation is an essential aspect of design
17.- Design involves multidisciplinary education
18.- Resources and support are required for design
19.- System design involves political processes

Source: (Challenger and Clegg 2011)

2.6.6 Weaknesses of socio-technical system

As any system, a socio-technical system has limitations that need to be taken into account before making a decision to use it. It is important however not to assume the applicability of socio-technical system in all cases.

The socio-technical system has been applied by different disciplines, using their own understanding. As a result of this, they focus aims on the social system or on the technical system, but not on both approaches. On the other hand, although managers consider important the use of socio-technical system approach, there has been a discussion about the lack of the use of socio-technical issues, owing to the difficulties in applying the methods and the disconnection between technical engineering issues and individual interaction issues with technical systems (Baxter and Sommerville 2011).

University of St Andrews (2012) explains the existence of barriers in the transition to other fields in the applicability in accordance with the cultural roots in a determined time, space and place:

- An absence of a clear terminology to define the structure of a socio-technical approach.
- Defining the abstraction to be used, according to the limits of the system and the attention paid on the technical aspects in detail.
- Incompatibility of humanistic values with managerial values, provoking a conflict in value systems.
- Difficulties in the identification of the evaluation conditions for the social approach of the system, generating an absence of agreed success criteria.
- A lack of synthesis rather than analysis, hindering the support for creating a successful system, rather than show a built system.
- Misunderstanding of multiple disciplines, halting the system development that other disciplines can contribute.
- A presented anachronism, because the approaches did not evolve to show the transforming nature of organisations and ways of working.
- An absence of support for recognising the proper stakeholders and users.

2.6.7 Use of socio-technical system approach in this research project

The tendency of transition to a sustainable regime has increased the attention of governments and society. The socio-technical approach supports this interest for making a transition in an active shape and facilitated way (Bush *et al.* 2017).

The identification of socio-technical barriers in renewable energy generation makes a more visible system. In this way, more options of electricity supplied from renewable sources are able to be understood and implemented (Sovacool 2009).

The socio-technical system has been well recognised and supported in different fields and disciplines. It offers the necessary components for assessing the global clean energy certificate markets in order to develop this research project. Socio-technical system approach provides a stronger tool for using as an analytical framework for this required evaluation.

3 Research Framework and Methodology

Previously, the second chapter introduced the socio-technical system approach as the analytical method to apply in this research project, which incorporates the enhancement made by some authors (Leavitt 1965; Clegg 2000; Davis *et al.* 2014) throughout the last decades. The socio-technical system framework constitutes a visual and a written explanation of how was adapted the socio-technical system framework for identifying the core best practices of the global clean energy certificate market. Subsequently, this analytical tool embeds and eases a wider understanding of the analysis and evaluation made in this research project.

3.1 Research strategy

In this section is introduced the research strategy that describes the applied methods in this research project, which are adapted to identify and evaluate the best practices of the global clean energy certificate market. Thus, a rationale is established for the selection of the methods to addressing the aims and objectives previously defined.

It was decided that the best analytical method to adopt for this research project was the socio-technical system approach. It is important to emphasise that some alternative approaches were discarded due to the complex tasks involved beyond the scope of a 1-year project.

For instance, it was considered to carry out interviews with leading experts from governmental energy agencies, generating and distribution power plants, regulatory authorities and financial institutions. This approach would include the design of a questionnaire and its application to the stakeholders of the evaluated countries.

In addition, it was also discarded a macroeconomic variables analysis which would usefully supplement and extend the investigation of the clean energy certificate markets performance. The macroeconomic variables analysis would require description and forecasting macroeconomics such as inflation rate, unemployment rate, interest rates, gross domestic product (GDP). The major problem of the macroeconomic variables analysis was to link them directly with the clean energy certificate market performance because of the expected difficulty of obtaining it in a reliable way.

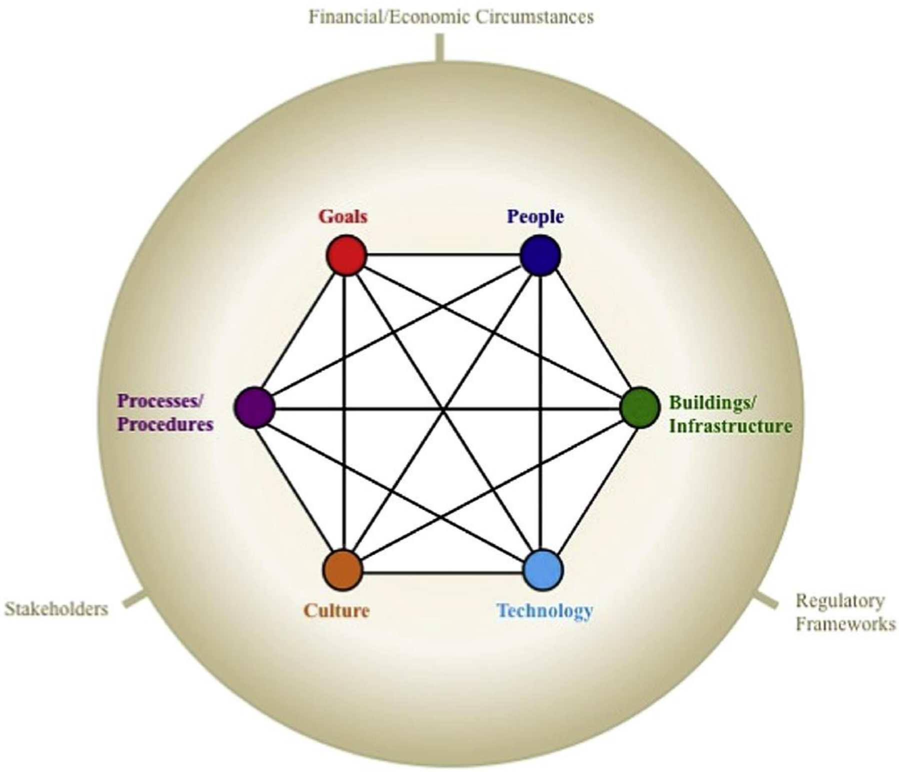
It is unfortunate that the study did not include the interviews application and the macroeconomic variables analysis owing to that the main drawback associated with the use of both approaches was the time limitation for a 1-year research project.

3.2 Socio-technical system theory approach

The socio-technical system theory indicates that technical and social factors have to be considered for designing and operating a new system. When one component of the system is modified, as a consequence, others components are modified subsequently. For this reason, the system has to be defined holistically (Clegg and Shepherd 2007).

Especially for this evaluation is used the extension of the socio-technical system framework for a more extensive perspective made by Davis *et al.* (2014) (Figure 3. 1), where is incorporated a regulatory framework, sets of stakeholders and financial/economic environment. This extension allows embracing a broader analysis for each evaluated country owing to their own context and a closer approach of social and technical characteristics.

Figure 3. 1: Socio-technical system, illustrating the interrelated nature of an organisational system, embedded within an external environment.



Source: (Davis et al. 2014)

Hence, goals, people, infrastructure, processes and procedures, technology, and culture are deemed interdependent and should be considered jointly (Challenger and Clegg 2011). The steps to populate a socio-technical framework through the analysis and understanding are indicated below (Table 3. 1).

Table 3. 1: The steps involved in analysing and understanding an existing socio-technical system

Step	Task description
1	Gather relevant data from appropriate sources, including key actors, stakeholders, subject matter experts, and internal and external documents.
2	Analyze and classify data, using techniques such as template analysis (King, 2004). Initial template consists of the socio-technical framework.
3	Identify and group key system factors. Visually represent the groups of factors on each node of the framework.
4	Consider the implication of the external environment in which the system is embedded within the node to which it relates.
5	Systematically consider relationships between each set of factors, and identify contingencies and direction of relationships.
6	Visually inspect the hexagon framework and assess underexplored or related areas, and reappraise evidence or seek input from colleagues and subject matter experts (e.g., with expertise in buildings and infrastructure).
7	Add any additional relevant factors that emerge from the data during analysis or following previous step.
8	If appropriate: Generate a timeline of key factors leading up to the event or scenario, grouped by the six factors. Classify as: long-standing issues (3 + months); issues immediately preceding the event (0−3 months); and factors involved on the day.
9	Test analysis on key stakeholders for accuracy, omissions and interpretations, and modify as necessary after discussion.
10	Generate key inferences regarding the system and how it works.

Source: (Davis et al. 2014)

3.3 CEC design features to evaluate

The definition of the design features for assessing the clean energy certificate markets was defined in accordance with the information provided in the literature review section. These design features were considered the most fundamental features in the design structure for the performance of the global clean energy certificate markets.

It is worth noting that the selection of the design features was made based on an analysis of documents with a critical review of the literature of each country. The countries that implement a clean energy certificate market as a governmental incentive for the deployment of renewable technologies, apply an overall design as discussed in Section 1.2.3. This clean energy certificate market design is compound by specific features, which may vary the design of the market for every particular context in each country. These design features may vary in accordance, for example, the setting of the renewable energy targets based on the status of the economy, the adequate accountability for the structure of the electricity market, the enactment of laws and regulations for a steady implementation of the market and the competitiveness of the market (Xin-gang *et al.* 2014).

The selection method of the design features has been performed in the following way. Firstly, a draft was made with the most common design features of the clean energy certificate markets applied by the regulatory authorities worldwide. Secondly, a document analysis was carried out in order to find and gather relevant information related to the design features for each country under evaluation. Finally, in the cases where the specific information for a determined design feature of a country was not found, this design feature was discarded for this research project.

The design features revised in the previous chapter in Section 2.5 were considered for evaluating the performance of global clean energy certificate markets. In particular, the *organisation of the market* design feature was split in *determination of CEC price* and *monitoring system or platform of CEC market* for a more detailed analysis. In addition, the features: *clean energy target, level of experience,* and *shelf life of CEC and sunset clause of CEC market* were added to the evaluation process to understand and comprehend the influence exerted in the performance of the markets.

Afterwards, the design features were allocated according to the socio-technical system components. Therefore, the allocation of features is shown below in Table 3. 2 and its explanation is described in the next sections.

Table 3. 2: Allocation of features in the CEC markets based on the socio-technical system components

Processes/ Procedures	Goals	People/ Institutions	Infrastructure	Technology	Culture
Determination of CEC Price	Clean energy target	CEC Trading	Monitoring system or platform of CEC market	Denomination of CEC	Level of Experience
Shelf life of CEC and sunset clause of CEC market	Renewable Purchase Obligation (RPO) target	CEC Market regulatory authority		Classification of CEC	
Penalty scheme					

3.3.1 Processes/Procedures

-The method for determining the clean energy certificate prices.

-The shelf life of clean energy certificates once issued and sunset clause of the clean energy certificate market determined by the regulatory authority.

-Determination of the penalty scheme for non-compliance of the renewable purchase obligation by the obligated entities and penalty fee charges.

3.3.2 Goals

-Clean energy targets on the renewable energy share set by the government.
-Renewable Purchase Obligation (RPO) quota of electricity generated from renewable energy sources.

3.3.3 People/Institutions

-Obligated entities and participants, who can buy and sell clean energy certificates.
-Clean energy certificate market regulatory authority, governmental and non-governmental institutions involved.

3.3.4 Infrastructure

-Monitoring system or platform of the clean energy certificate market to supervise trading operations.

3.3.5 Technology

-Denomination of clean energy certificate per megawatt-hour (MWh) generated from renewable energy sources.
-Classification of the clean energy certificates by generation capacity or generation technology.

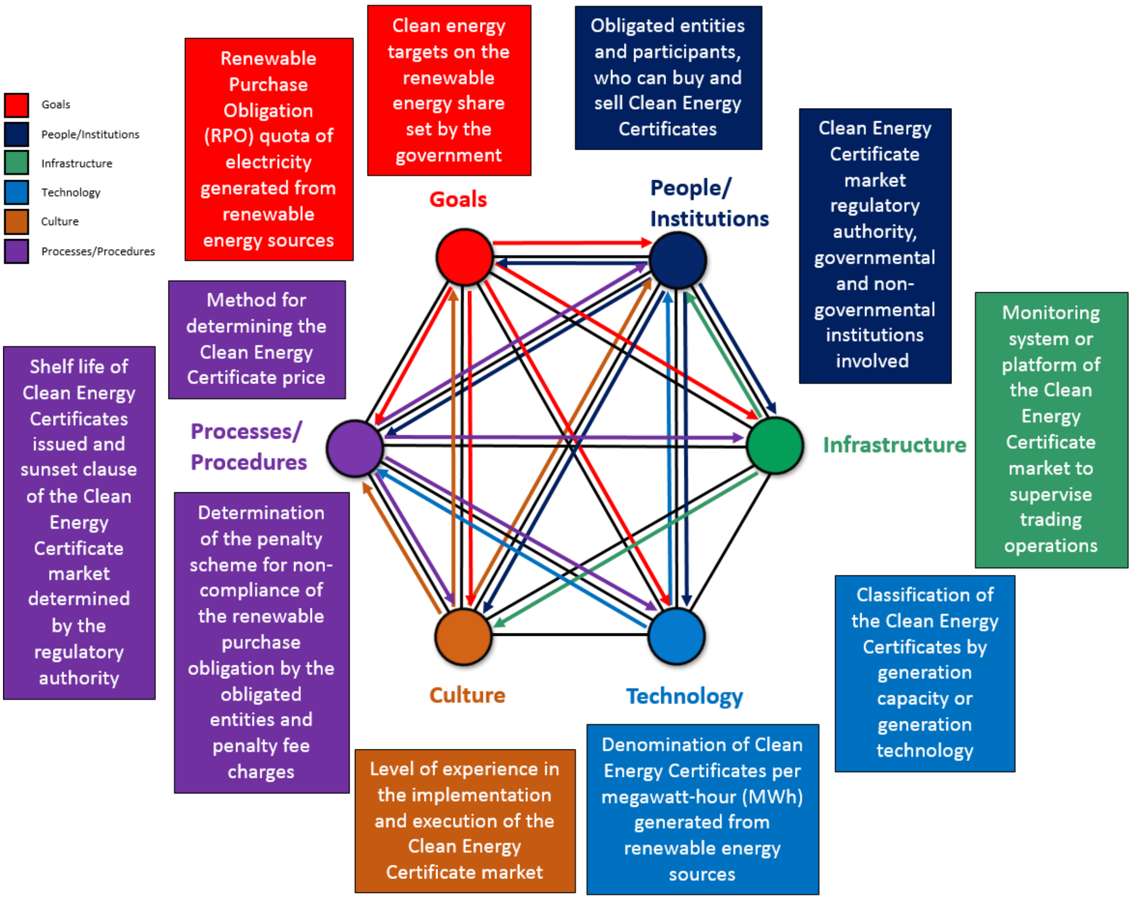
3.3.6 Culture

-Level of experience in the implementation and execution of the clean energy certificate market.

3.4 CEC market connections definition

In this section, the connections are identified, as well as their interactions amongst the components within the socio-technical system framework of the clean energy certificate market (Figure 3. 2).

Figure 3. 2:Socio-technical system of the clean energy certificate market, adapted from (Davis et al. 2014)



3.5 Data collection

The countries selected for this research project were Sweden and Norway, United Kingdom, Australia, India and the state of California in the United States. These clean energy certificate markets were selected due to they have a high penetration of renewable energies with diverse market characteristics and different geographies.

The selection process and the considerations involved in order to define the countries to be evaluated were based on a documents analysis where the information related to the design features to evaluate was available.

Firstly, Chile was contemplated because of the similarities that exist with Mexico for being both Latin-American countries. In this case, the country of Chile was discarded due to the absence of information related to some design features for evaluation. Secondly, it was intended to evaluate the clean energy certificate markets of developed countries such as Belgium, Italy, Poland and Romania. In the same way, the information of these developed countries related to the design features was not found.

In the final document analysis, it was required to gather the whole information related to each design feature for evaluation completely before considering a country for evaluation in this research project. Hence, the results of the document analysis indicated the definitive selection of the countries for evaluation in this study.

Sweden and Norway were selected because these countries established a clean energy certificate joint market. The evidence from this joint market suggests the exploration for Mexico in terms of the creation of a joint market through the North American Free-Trade Agreement (NAFTA) with Canada and the United States.

The United Kingdom was contemplated for the importance of the contribution to its renewable energy generation share from wind energy (GWEC 2017). A reasonable motive to select this country is the Mexico's wind potential highlighted in Table 1. 1.

The Australian clean energy certificate market was considered due to its installed capacity of solar PV pointed out in Figure 4. 4 (Clean Energy Council 2017). The market of Australia reveals the need for further investigation for acquiring technical guidance for the solar resource available in Mexico which is the second most important potential in the country (Table 1. 1).

India's market was studied because this country accounts for the highest solar energy potential in the world with 5,000 trillion kWh per year (Kumar and Agarwala 2013a). In addition, it was important to include India in the case study as it is a developing country similar to Mexico. This is in contrast to the other countries in the study which are already developed.

California's market in the United States was selected for its location. Mexico and the United States share a border and California is one of four states of the United States that spans the border with Mexico. Also, the solar PV capacity installed in California (REN21 2017) is essential to evaluate owing to the Mexican solar energy potential (Table 1. 1).

It is important to note however, that the clean energy certificates have different labels in each country, *electricity certificates* in Sweden and Norway, *renewable obligation certificates* in the United Kingdom, *renewable energy certificates* in Australia and India, and *renewable portfolio standards* or *renewable energy credits/certificates* in the state of California in the United States.

The collection of data was made through literature searching of each country to evaluate and the information related to the Mexican market. The collected literature was related to an extensive review of academic information of a particular body of research work, governmental, energy agencies and industrial sector information. It is worth noting that the data collection was sourced via internet searching through the Web of Science Core Collection for academic or scientific research publications. Similarly, the governmental information was retrieved from the energy ministries or departments of the evaluated countries, as well as publications from international energy agencies and private energy sector websites.

The procedure of documents analysis was carried out through finding, selecting, synthesizing and appraising the information related to the design features of each country. There was found information from more than one source per each design feature in order to corroborate the evidence of the information. It is interesting to outline that the identification of the relevant information was made in order to separate it from the non-relevant information.

The procedure for the data collection was to gather relevant information concerning to the design features defined previously, keeping a uniformity in the gathered information, in order to follow the same pattern for easing the analysis process of all the evaluated countries. The data collection process helped to learn the meaning, improve understanding and uncover insights of the evaluated clean energy certificate markets.

3.6 Data analysis

After the data collection process was completed, the next step was the analysis and classification of the data. This step was made through the socio-technical system approach in accordance with the design features of each clean energy certificate market of the evaluated countries. The design features were analysed and classified in a structured order for each evaluated country. Then, in terms of a comparative analysis, it was necessary to use a comparison table (Table 4. 6) as an analytic visual support, summarising the relevant information for each design feature of all the evaluated countries and the Mexican information was also included.

Following this, it was systematically identified the design features considering the relationships amongst the socio-technical system components. Equally, the existence of important findings was visually located, outlining the best practices and failures within the connections and interactions in the socio-technical system as a result of the analysis made in each clean energy certificate market. These results were analysed based on the principles of socio-technical systems design established by Challenger and Clegg (2011).

Once the results of evaluated countries were analysed, an assessment of the Mexican clean energy certificate market was made in order to find the best practices based on the lessons learnt from evaluated countries. On the other hand, the gaps in the Mexican clean energy certificate market were also identified based on the previous analysis.

4 Results and discussion

The results and discussion in this chapter explore the design features defined in the third chapter, where the design features information is collected and analysed according to the socio-technical system approach for countries evaluation.

The structure of this chapter starts with the description and analysis of the design features of the evaluated markets. Then, the best practices and failures are analysed using the socio-technical system approach. The analysis and evaluation process are based on the performance of each clean energy certificate market, in order to identify the best practices and failures within the socio-technical system approach. It is worth noting that in the evaluation of the countries some comparisons are made with the design features of the Mexican clean energy certificate market outlined in Section 1.4.

The findings of this study which are considered to be *best practices* are the actions that the Ministry of Energy of Mexico, policymakers and other stakeholders can pursue to ensure that the Mexican clean energy certificate market can effectively coevolve with increasing penetrations of renewable energy. Hence, the best practices can lead the development and innovation of the Mexican market design features for encouraging market operators to adopt guidelines to improve the market efficiency.

In contrast, the findings defined as *failures* in this research project are the cases studied where the design features of the assessed markets do not meet the desirable and intended objective. It is also considered as a failure when the core need or issue has not been resolved or met which can result in a below-expected design feature.

Finally, when an assessed design feature is not categorised as best practice or as a failure, it is regarded as a *neutral*. Therefore, in order to establish an easy way to describe and explain the analysis made to each country in this chapter, the findings of the best practices and failures are indexed with a letter in brackets in the figure of the socio-technical framework followed by the description of the best practices and failures. Likewise, these descriptions are indexed with letters and footnotes. Then, in terms of expanding the explanation for a better understanding for the reader, the letters are also found in Table 4. 6 and Table 4. 7 for analytical and comparative support, respectively.

Afterwards, the best practices and failures of evaluated countries are linked and summarised in a comparative table. Also, the *principles of socio-technical systems design* (Table 2. 2) and the components of the socio-technical approach are linked to the best practices and failures for a better understanding of the findings.

At the end of the chapter, the design features within the components of the socio-technical system approach are identified and analysed in summary in Section 4.6, where are emphasised the best practices and failures of evaluated countries.

4.1 Sweden and Norway

4.1.1 CEC market in Sweden and Norway

In the last 50 years, Sweden and Norway have built diverse energy systems each other with an important energy production from renewable sources. Norway became the principal producer of hydropower within Europe during last century, as the main way of electricity production. However, Sweden has a bigger renewable energy production than Norway in terms of renewable sources different than hydropower. Therefore, there has been important progress on renewable energy production shares for auto-consumption with 50% for Sweden and 64% for Norway (Ydersbond 2014).

4.1.1.1 Level of experience and clean energy targets

A joint electricity certificate market was signed by the governments of Sweden and Norway. They both agreed that the commencement date for the market on 1 January 2012. This market was based on the Swedish electricity certificate system (Electricity Certificates Act) created in 2003, considering a quota obligation as the main mechanism to foster the renewable electricity (NVE 2016). Accordingly, renewable energy targets were settled by Sweden in 49% and by Norway in 67.5% by 2020 (Sigurd Næss-Schmidt *et al.* 2013). An amendment was added to this bilateral agreement on 1 January 2016, resulting in a rise in the renewable energy share target. They set a quota of electricity generated from renewable sources of 28.4 TWh by 2020, where 2 TWh were added to 26.4 TWh (NVE 2016). Hence, Sweden will be responsible for 15.2 TWh and Norway for 13.2 TWh (IEA 2017b).

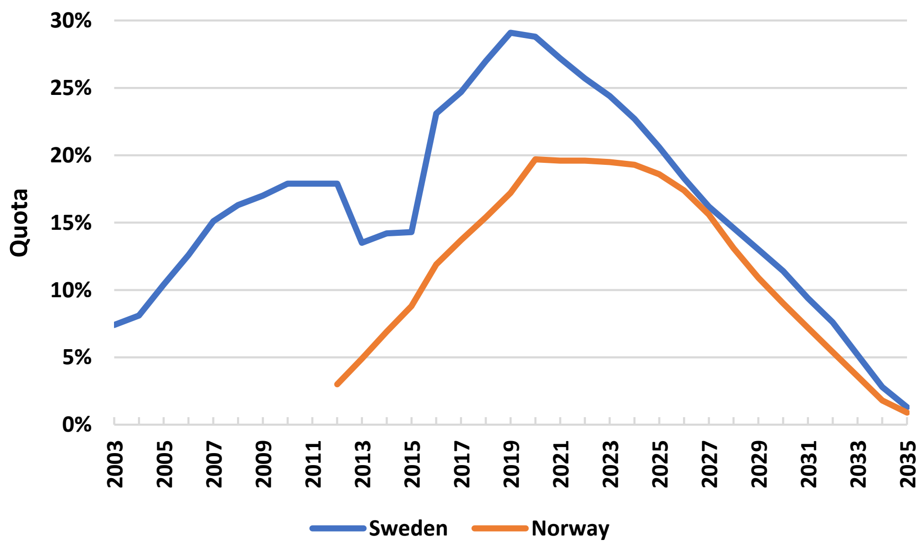
4.1.1.2 CEC Trading

The Swedish and Norwegian electricity certificate system works under a quota obligation scheme towards electricity suppliers, electricity consumers and industries, with the need of renewable energy certificates depending on the amount of their electricity sales and consumption each year. Thus, these obligated entities are eligible to receive electricity certificates for 15 years, in accordance with the fulfilment of the electricity delivered from a renewable energy source considered in the mutual agreement (IEA 2013).

4.1.1.3 Renewable Purchase Obligation (RPO) target

In terms of the Swedish-Norwegian legislation, the electricity certificate market outlines a steadily rise in quota obligations until 2020. These quota obligations are specific for Sweden and Norway, acting as an incentive for boosting the certificate trading operations. The quota obligations established for the certificate market participants are 27.0% for Sweden and 15.4% for Norway in 2018 (Figure 4. 1), these quota obligations are different for each nation due to a future calculation-relevant electricity consumption as well as the plants included in the financing transition plan (NVE 2016).

Figure 4. 1: Quota Obligations for Sweden and Norway



Source: (NVE 2017)

In Norway, the electricity certificate market has a time span from 2012 to 2035, in Sweden, this market was established in 2003 and planned to end in 2035, without any further planned action after 2035. In each country, the quota obligations were settled according to a calculation on the future electricity consumption, in case of a variation from the expected consumption, an adjustment has to be necessary, for instance, in 2015 there was an adjustment in the quota obligation (NVE 2016). Thus, the last quota obligations will be 1.3% for Sweden and 0.9% for Norway by 2035 at the closure of the electricity certificate market (NVE 2017).

4.1.1.4 Monitoring system or platform of CEC market and CEC market regulatory authority

The monitoring systems in charge of the electricity certificate market transactions are Cesar (Swedish Electricity Certificate Register), who is operated by the Swedish Energy Agency (Energimyndigheten) from 2015; Svenska Kraftnät was the former responsible for the Swedish accounting systems (Energimyndigheten 2017a) and NECS (Norwegian Energy Certificate System) is operated by Statnett since 2012 in Norway (Statnett 2017). The Swedish Energy Agency and the Norwegian Water Resources and Energy Directorate (NVE) manage the electricity certificate system and applications, supervise market participants, sanctions, quota obligations and the regulatory framework, and provide information of the electricity certificate market performance (NVE 2013).

The Swedish Energy Agency (Energimyndigheten) is a government agency in control of the energy policies analysis and reports statistics, forecasts and projections, approves the electricity plants and fulfilment issues, promotes the use and RD&D of renewables technologies (IEA 2013). The Norwegian Water Resources and Energy Directorate is in charge of the Norwegian energy and water resources, concedes licenses for small hydro, wind power and heating plants. This agency works under the direction of the Ministry of Petroleum and Energy (MPE) (IEA 2017b).

4.1.1.5 Determination of CEC price

The renewable energy certificate trading operations take place in a common electricity certificate market for Sweden and Norway, where the certificate price is established depending on supply and demand. Thus, trading interactions of quota obligations are between energy generators and energy consumers or they can be made through brokers. Due to the increasing renewable capacity, the supply of electricity certificates was stable from 2003 to 2012, indeed, during the period of 2003 to 2005, the demand of electricity certificates was below than the supply. Nonetheless, from 2006 to 2010, demand and supply remained stable, consequently, the electricity certificate prices rose significantly. On the contrary, the price of certificates went down dramatically in 2011, because of a climb in the accumulation of certificates as a result of a greater supply of certificates than the demand. In 2013, the supply of certificates and the licensed renewable capacity declined as a consequence of biomass capacity and wind power phase-out (Tang and Rehme 2017).

4.1.1.6 Classification and denomination of CEC

The Swedish and Norwegian electricity certificate market is based on a technology-neutral scheme, in order to foresee a profitable clean technology market for promoting investments. Electricity certificates can be issued from these renewable technologies: solar, wind, hydro and tidal power, solid biofuels and peat in CHP plants (NVE 2014). Energy generators obtain from the government of Sweden and Norway one electricity certificate per 1 MWh of their renewable energy production. The power plants are allowed to receive electricity certificates by the Swedish Energy Agency approval in Sweden and by the Norwegian Water Resources and Energy Directorate (NVE) approval in Norway. The certificate generation term is for 15 years of production from the renewable energy sources previously mentioned (Hustveit *et al.* 2015).

4.1.1.7 Shelf life of CEC and sunset clause of CEC market

A recurrent demand is created in the Swedish-Norwegian certificate market as a consequence of the quota obligation fulfilment each year in the states of Sweden and Norway. Electricity certificates have one year of validity period to be used in terms of meeting the quota obligation, thus electricity producers must purchase new certificates to meet the quota obligation for the next year (Energimyndigheten 2017c). Nonetheless, the electricity certificates will not be issued further than 2035 (Europe 2015).

4.1.1.8 Penalty scheme

On March 1st of each year, is the last day for market participants to submit to the Swedish Energy Agency the information regarding the consumption and the sale on electricity during the preceding year. This information also includes the number of certificates of renewable electricity generated in accordance with their quota obligation (Fagiani and Hakvoort 2014). On the other hand, in Norway, the grid companies submit the information to Statnett (NVE 2016). In the case of non-fulfilment of quota obligation by suppliers, a penalty fee has to be paid, calculated in 1.5 times the preceding year certificate price (Fagiani and Hakvoort 2014). Therefore, the quota obligation fee for the period 2018 is 187.95 NOK or 192.71 SEK ($24.59 USD) (Energimyndigheten 2017b).

The Swedish-Norwegian electricity certificate market scheme is designed to support the developed renewable technologies, which need a lower government grant, in comparison to the new and expensive technologies which need a higher government grant. For this reason, the investment for cheaper technologies is guaranteed. In addition, continuous adjustments to quota obligations are made for certificate price stabilisation, in order to maintain a supply and demand electricity from renewable sources. Thus, certainty in the electricity certificate market is primordial to attract greater investments and for better market development (Hustveit and Frogner 2015).

4.1.2 Market analysis and comparisons with the Mexican CEC

Sweden was one of the first countries in the world to establish an electricity certificate market since 2003, afterwards alongside Norway, a country who has had a hydropower production for around 5 decades, created a joint electricity certificate market in 2012 with ambitious renewable energy targets of 28.4 TWh of electricity produced from green technology sources by 2020 (NVE 2016).

Evidently, there are some similar aspects with the Mexican Clean Energy Certificate market, for instance, both countries have monitoring systems who register the certificate trading operations (CRE 2017). For the Swedish and Norwegian markets are Cesar and NECS, regulated by the Swedish Energy Agency and Statnett, respectively (NVE 2016). Similarly to the Mexican market, electricity certificate prices are defined by supply and demand of these certificates (Tang and Rehme 2017). According to the legislation, the Swedish-Norway electricity certificate market applies a technology-neutral quota scheme (IEA 2013), as well as Mexico (SENER 2016c). Indeed, it is possible because of the abundant renewable energy resource potential. In this way, energy generators obtain one certificate per 1 MWh generated from renewable energy sources (Hustveit *et al.* 2015).

It is important to note, however, that several differences exist between the electricity certificate markets of Sweden-Norway and Mexico, this can be seen in the case of the period for the Swedish-Norwegian approved plants that were eligible to receive electricity certificates, it is only for 15 years (IEA 2013), whereas in Mexico is for 20 years (CRE 2017). In addition, there is an important difference for quota obligations, while for Sweden is 27.0% and for Norway is 15.4% by 2018 with an increasing rate until 2020 (NVE 2016); compared with the Mexican quota obligation in the same year, is 4.7 times lower than the Swedish quota obligation and 2.7 times lower than the Norwegian quota obligation (SENER 2017b).

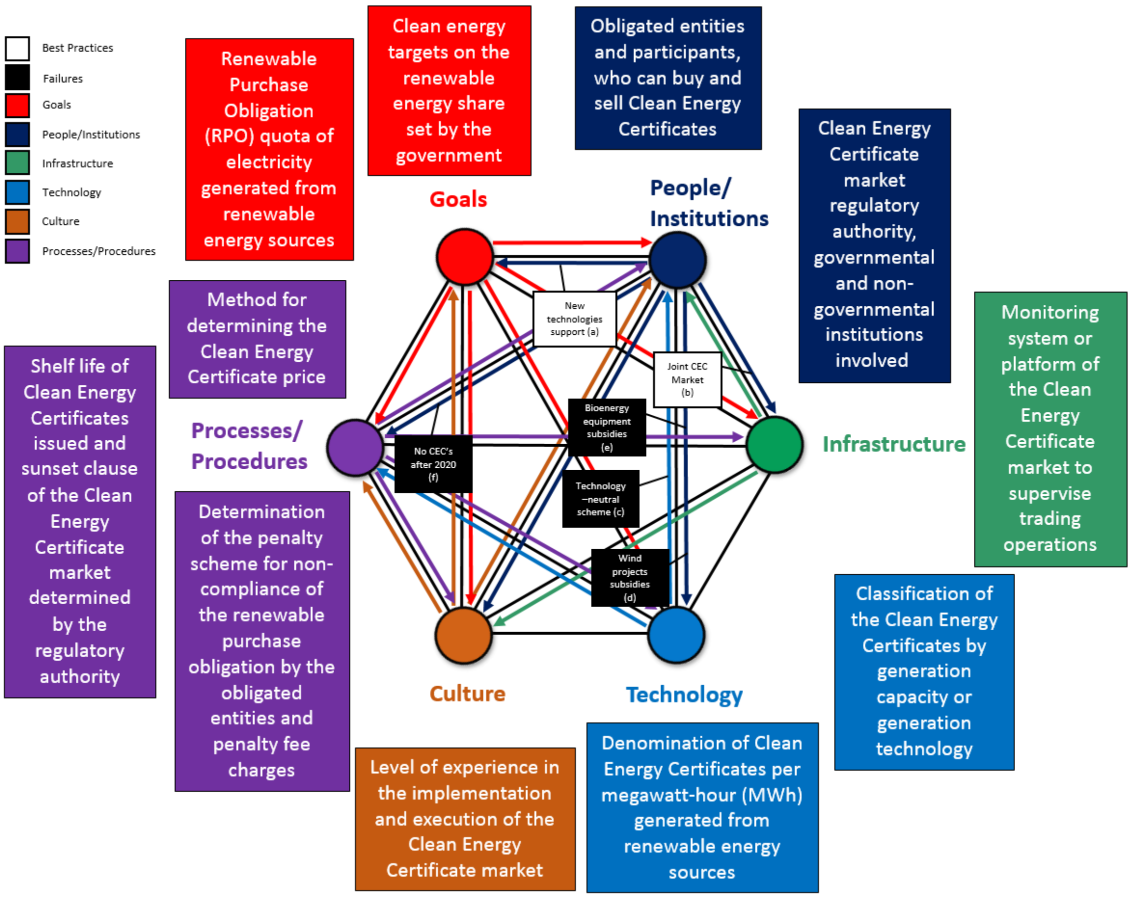
In the same way, the market participants have only one year in terms of cancel electricity certificates corresponding to their quota obligations (Energimyndigheten 2017c), conversely to the Mexican market, the electricity certificates do not expire until they are cancelled (CRE 2017). Nonetheless, a further point should be considered, the Swedish-Norwegian legislation determined that the sunset clause of the electricity certificate market is settled by 2035 (Energimyndigheten 2017c).

Finally, the last difference is defined by the Swedish and Norwegian relevant Acts and Regulations, in terms of the penalty fee calculation in case of non-fulfilment the quota obligation by energy producers, which is based on the certificate price, resulting in 1.5 times the certificate price of the preceding year (Fagiani and Hakvoort 2014). In comparison with the Mexican penalty fee calculation, which is based on the value of 6 ($27 USD) to 42 ($189 USD) minimum wage, depending on the non-fulfilment severity (CRE 2016b).

Then, it might be concluded from the Swedish-Norwegian market analysis, that the implication of a prompt response in the quota obligation adjustments, has been beneficial for the stabilisation of the electricity certificate prices, in order to maintain a supply and demand of electricity from renewable sources. Indeed, attracting the attention of investors is primordial for strengthening the development of the electricity certificate market in Sweden and Norway in accordance with the renewable energy goals.

4.1.2.1 Analysis from the socio-technical perspective

Figure 4. 2: Analysis from the socio-technical perspective of the Swedish and Norwegian CEC market



4.1.3 Best practices and comparisons with the Mexican CEC

4.1.3.1 New technologies support (a)[1]

Indeed, in order to put more efforts on new renewable technologies, the Swedish and Norwegian energy agencies (People/Institutions) have not set new renewable targets longer than 2020 (Goals) for stopping the support for mature technologies. This is the case of hydropower, which does not need the electricity certificate market support for the large-scale exploitation, in terms of avoiding the hindering of new renewable technologies deployment (principles 1, 4, 5, 16). For this reason, it is relevant for the Mexican authorities, to regulate the clean energy certificate market when necessary, bearing in mind that a prompt response and action are indispensable for the energy sector, considering as a priority factor, the development of new renewable technologies in Mexico.

4.1.3.2 Joint CEC market (b)[2]

Indeed, the interaction of two or more countries into a joint market, makes a strong and solid market. This was evident in the most recent amendment of the renewable target by adding 2 TWh (NVE 2016). This joint market has resulted in greater benefits in Sweden and Norway (People/Institutions) for energy generation from renewable sources. Nowadays, for Mexico, the agreement for a joint market (Infrastructure) with neighbouring countries cannot be promising in the short term due to the recent announcement of the United States government withdrawal from the Paris Agreement, weakening the efforts to combat the climate change, halting the use of renewable sources. In addition, Mexico is facing a difficult renegotiation of the North American Free-Trade Agreement (NAFTA) with Canada and the United States, reducing the likelihood of a joint certificate market for Mexico over the next few years (principles 2, 6, 19).

[1] (a) This best practice can be found in Figure 4. 2 and in Table 4. 6 for analytical and comparative support, respectively.
[2] (b) This best practice can be found in Figure 4. 2 and in Table 4. 6 for analytical and comparative support, respectively.

4.1.4 Failures and comparisons with the Mexican CEC

4.1.4.1 Technology–neutral scheme (c)[3]

A large Swedish and Norwegian renewable share has been based on hydropower, with a share of 72.7% for Sweden (IEA 2017i) and 97.9% for Norway (IEA 2017e) of electricity generation from renewable sources in 2015. In the same way, an important failure of the Swedish and Norwegian electricity certificate market has been the technology-neutral scheme, due to the hydropower potential of Sweden and Norway that left behind other renewable energy sources. This technology-neutral scheme hampered the introduction of new renewable technologies instead of creating competitive renewable shares different to hydropower for electricity production, for this reason, new renewable sources cannot compete under this technology-neutral scheme (Technology). As a consequence from this, the innovation and development of new renewable technologies were disregarded by authorities (People/Institutions), being hydropower a renewable source which main efforts were focused on its exploitation (principles 3, 16).

4.1.4.2 Wind projects subsidies (d)[4]

Then, the subsidies for new wind energy projects will not be offered by the Swedish and Norwegian governments (People/Institutions) further than 2020, hindering the deployment and investment of this renewable energy owing to the size of wind projects (Technology). Likewise, these subsidies are needed to attract the attention of wind energy investors because of these projects are profitable in a long-term (principles 4, 12, 15, 18).

4.1.4.3 Bioenergy equipment subsidies (e)[5]

Evidently, the Swedish-Norwegian and Mexican shares of biofuel and waste are low for electricity generation, as a consequence of this, the governments of the joint electricity certificate market (People/Institutions) have offered subsidies on equipment to produce bioenergy (Technology), to encourage the growth of this type of energy, but this

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[3] (c) This failure can be found in Figure 4. 2 and in Table 4. 6 for analytical and comparative support, respectively.
[4] (d) This failure can be found in Figure 4. 2 and in Table 4. 6 for analytical and comparative support, respectively.
[5] (e) This failure can be found in Figure 4. 2 and in Table 4. 6 for analytical and comparative support, respectively.

incentive has not been a motivation to increase the electricity production in the joint market from 13.9 TWh in 2012 (IEA 2017c; IEA 2017g) to 12.4 TWh in 2015 (principles 4, 12, 15,18) (IEA 2017d; IEA 2017h). It is important to note, however, that in the current Mexican regulatory framework does not exist this kind of supporting aids, taking into account the low installed capacity of bioenergy in Mexico, this subsidy would not be an incentive to increase the electricity production from biofuel and waste.

4.1.4.4 No CEC's after 2020 (f)[6]

Finally, an equally significant aspect of the Swedish and Norwegian governments (People/Institutions), in accordance with their regulatory framework is that the generation plants established after 31 December 2020 will not be eligible to issue electricity certificates (Processes/Procedures), this implies that they have omitted to foresee future renewable energy investments for the electricity certificate market (principles 5, 16). Therefore, long-term investments after 2020 for the renewable energy sector are not considered under this system, addressing for the amendment or implementation of new policies for boosting the renewable energy sources.

4.2 United Kingdom

4.2.1 CEC market in the United Kingdom

4.2.1.1 Level of experience

The United Kingdom was one of the first countries in the world to establish a Renewable Obligation Certificate (ROC) market in 2002 (Bunn and Yusupov 2015). In 2000, the total electricity produced from renewables represented 2.8%; once implemented the renewable obligation certificate market, the total electricity produced from renewables represented 7.2% in 2010 (DECC 2014). In 2002 was established the renewable obligation certificate market in England, Wales and Scotland, afterwards in North Ireland by 2005 (IEA 2017f). The renewable obligation certificate market is enacted in the 2009 No. 785 - Electricity, England and Wales - The Renewables Obligation Order 2009 to aim a greater use of renewable energy in electricity generation (DECC 2014).

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[6] (f) This failure can be found in Figure 4. 2 and in Table 4. 6 for analytical and comparative support, respectively.

4.2.1.2 Clean energy targets

In 2010, the National Renewable Energy Action Plan (NREAP) set a target for the United Kingdom of 15% of renewable energy share for electricity generation or 238 TWh by 2020, where the large-scale projects must produce 108 TWh, and 130 TWh with biofuels, heating and small-scale projects, in accordance with the recent technology-banding scheme (IEA 2012a).

4.2.1.3 CEC Trading

The obligated entities under the renewable obligation certificate scheme are the electricity suppliers for over a maximum of 20 years. The renewable obligation certificate market has closed to new entities from April 2017 and Contracts for Difference (CfD) is the new scheme for electricity producers from renewable sources. It is worth noting that the market was closed for solar and onshore wind energy generators from 2016 (Commons 2016).

4.2.1.4 Renewable Purchase Obligation (RPO) target

The buy-out price and obligations are published each year in February by the Office of Gas and Electricity Markets (Ofgem), this calculation is based on the Retail Prices Index (RPI) of the preceding year (Table 4. 1). Therefore, for the period from 1 April 2017 to 31 March 2018 the renewable obligation is 40.9% in England, Wales and Scotland and 16.7% in Northern Ireland (OFGEM 2017b).

Table 4. 1: Buy-out prices and obligation levels 2010-11 – 2017-18

Obligation Period (1 April - 31 March)	Buy-Out Price	Obligation for England & Wales and Scotland (ROCS/MWh)	Obligation for Northern Ireland (ROCS/MWh)
2010-11	£36.99	0.111	0.0427
2011-12	£38.69	0.124	0.055
2012-13	£40.71	0.158	0.081
2013-14	£42.02	0.206	0.097
2014-15	£43.30	0.244	0.107
2015-16	£44.33	0.290	0.119
2016-17	£44.77	0.348	0.142
2017-18	£45.58	0.409	0.167

Source: (OFGEM 2017b)

4.2.1.5 Monitoring system or platform of CEC market and CEC market regulatory authority

The administration of the monitoring system of the renewable obligation certificate market is Ofgem E-Serve through the system “Renewables and CHP Register” on behalf of the Office of Gas and Electricity Markets. In addition to the certificate operations, Ofgem E-Serve receives and redistributes the funds of the buy-out and late payments, and publishes the operation and compliance annual reports (OFGEM 2017d). The Office of Gas and Electricity Markets is an independent national regulatory authority, who is in charge of the renewable obligation certificate market. This office works in an autonomous way in the energy industry and is a non-ministerial department of the government, which is administrated by the Gas and Electricity Markets Authority (GEMA) (OFGEM 2017a).

4.2.1.6 Determination of CEC price, classification and denomination of CEC

The price of the renewable obligation certificates is determined by the supply and demand of the market in monthly auctions through the online service “e-ROC”, who provides the trade information of the renewable obligation certificate operations since 2002. The Non-Fossil Purchasing Agency (NFPA) is in charge of the e-ROC functioning (Bryan, Lange and MacDonald 2015). Indeed, when the renewable obligation certificate market was implemented in 2002, the renewable obligation was under a technology-neutral scheme, where one renewable obligation certificate was issued for each megawatt-hour generated by eligible renewable energy source; but in April 2009 the technology-neutral scheme was replaced by a technology-banding scheme to support specific renewable technologies at different levels from 0.5 MWh/ROC to 10MWh/ROC (Table 4. 2) for wind energy, bioenergy power, solar energy and hydropower (Commons 2016).

Table 4. 2: Amount of electricity in megawatt-hours (MWh) to be stated in a ROC issued for electricity generated

Generation type	MWh/ROC	Generation type	MWh/ROC
Landfill gas heat recovery	10	Building mounted solar PV	0.75
Closed landfill gas	5	Dedicated biomass	0.75
Co-firing of regular bioliquid	2	Ground mounted solar PV	0.75
Electricity generated from sewage gas	2	Anaerobic digestion	0.5
Low-range cofiring	2	Advanced gasification/pyrolysis	0.5
Hydroelectric	1.5	Dedicated energy crops	0.5
Mid-range cofiring	1.5	Geothermal	0.5
Energy from waste with CHP	1	Offshore wind	0.5
Geopressure	1	Standard gasification/pyrolysis	0.5
High-range cofiring	1	Tidal impoundment – tidal barrage	0.5
Onshore wind	1	Tidal impoundment – tidal lagoon	0.5
Station conversion	1	Tidal stream	0.5
Unit conversion	1	Wave	0.5

Source: (DECC 2014)

4.2.1.7 Shelf life of CEC and sunset clause of CEC market and penalty scheme

The renewable obligation certificates have a shelf life of 1 year, therefore, electricity generators can surrender them in the same obligation period (OFGEM 2017d). The regulatory authority established a maximum period for the renewable obligation certificate market not longer than 31 March 2037 (DECC 2014). Another, significant factor in case of non-compliance of the renewable obligation, Ofgem set a buy-out price of £45.58 ($61.47 USD) per MWh for the obligation period 2017-2018 (Table 4.1), it is important to note that this buy-out price is published every year by the Ofgem (OFGEM 2017b).

4.2.2 Market analysis

The renewable electricity generation through renewable obligation certificates has impacted the amount of total electricity generation share in the United Kingdom from 1.8% in 2002 to 7.2% in 2010. Although the target of 10% in the amount of renewable electricity generated by 2010 was not reached; the United Kingdom government was committed to continuing the adoption of green technologies. This shortfall was due to the lowest rainfall since 2003 and the lowest wind speeds since 2000 that affected seriously the load factors during this period, especially for hydropower and wind energy. However, onshore wind energy faced non-economic barriers like planning and social acceptance (IEA 2012a).

The embracing of the technology-banding scheme in 2009 was a successful measure for the offshore wind energy deployment, owing to the fact that most of the wind projects were supported by renewable obligation certificates (GWEC 2016b). As a consequence of this implementation, the United Kingdom is currently the largest offshore wind market in the world, accounting with 5.2 GW of total installed offshore wind capacity along 27 wind farms (GWEC 2017). This implies that the United Kingdom is the sixth-largest in the world with 13.6 GW of total installed wind capacity, including onshore and offshore installed wind capacity (GWEC 2016a).

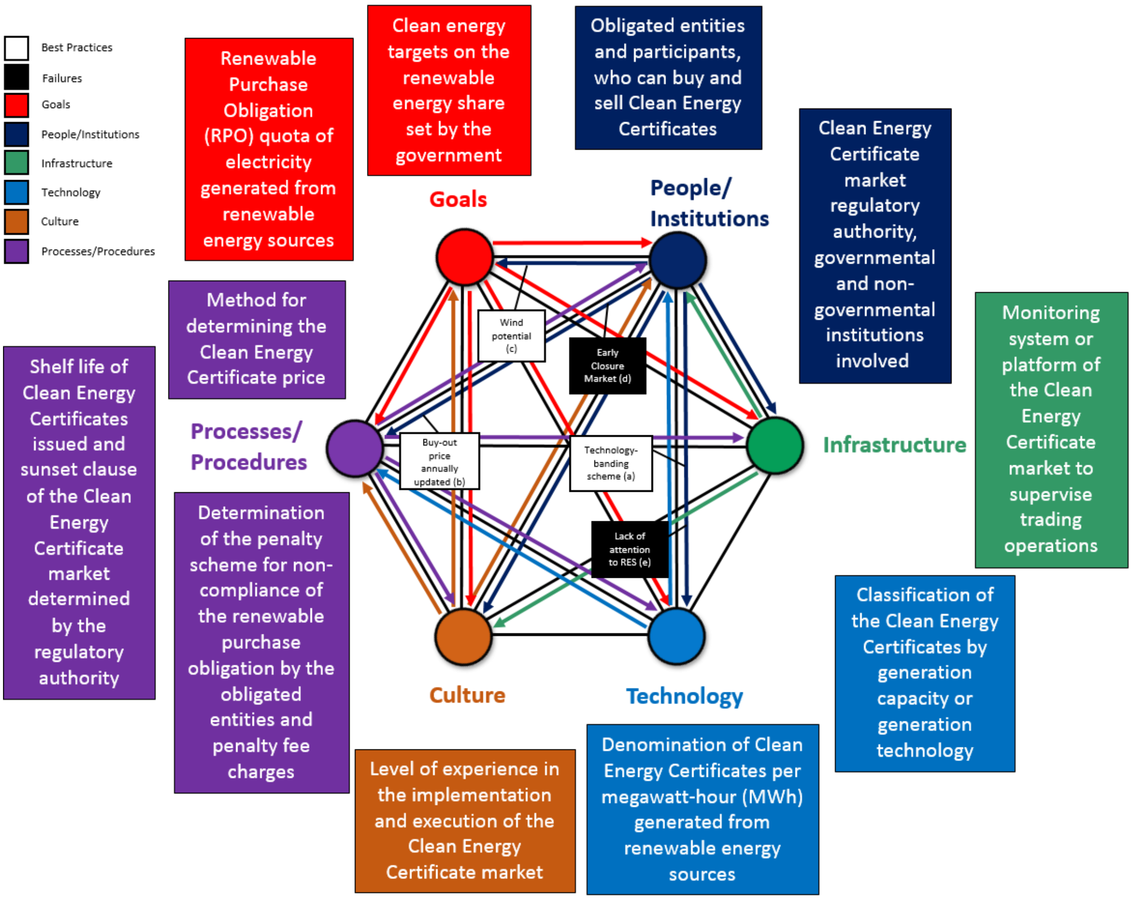
On the other hand, the United Kingdom government has announced in the Electricity Market Reform (EMR), the closure of the renewable obligation certificate market by 1 April 2017 for new projects, supporting the existing electricity suppliers until 2037 when the market will end (Commons 2016). In May 2015, the Conservative Party included in the Conservative Party Manifesto 2015 the pledge of halt the spread and end the public grant for onshore wind farms projects (Party 2015). Resulting from this, in the early closure of the renewable obligation certificate market for onshore wind farms one year early by April 2016, being open up to 1 April 2017 for offshore wind projects, but investors hardly tackled the deadline for these projects (GWEC 2016b).

The renewable obligation certificates market is being replaced by the Contract for Difference (CfD) system from October 2014, in accordance with the Electricity Market Reform (EMR), where electricity suppliers receive the difference of a contracted electricity price named “strike price”, that reflects the renewable technology investment and the average electricity price in the United Kingdom. This system was designed to offer certainty and stability to electricity suppliers, besides, to reduce the electricity price volatility (DBEIS 2017).

Currently, the renewable obligation certificate market is the major mechanism to foster the deployment of electricity generation from renewable sources in the United Kingdom and the principal renewable certificate market in the world with important amendments on its regulatory framework, resulting from this, in significant progress in the use of renewable energy for electricity generation, in particular for wind energy generation.

4.2.2.1 Analysis from the socio-technical perspective

Figure 4. 3: Analysis from the socio-technical perspective of the United Kingdom CEC market



4.2.3 Best Practices and comparisons with the Mexican CEC

4.2.3.1 Technology-banding scheme (a)[7]

The change from the technology-neutral to the technology-banding scheme in 2009 (Commons 2016), was a rationale for the deployment of the solar power in the United Kingdom. In 2002, when the renewable obligation certificate market was launched, the generation of electricity from solar PV was 3 GWh (IEA 2017k), whereas in 2009 was 20 GWh (IEA 2017l). Therefore, as a consequence of the technology-banding scheme enactment, the generation of electricity was 7,561 GWh in 2015 (IEA 2017m). Certainly, the regulatory authority of the United Kingdom (People/Institutions) could change to the technology-banding scheme (Technology) to increase dramatically the amount of

[7] (a) This best practice can be found in Figure 4. 3 and in Table 4. 6 for analytical and comparative support, respectively.

electricity generated (principles 3, 12). This was an assertive decision and a clear example in showing how the Mexican authorities can design this kind of amendments in favour of the renewables energies. It could also be said that the solar energy the most important source in terms of potential in Mexico.

4.2.3.2 Buy-out price annually updated (b)[8]

The annual update of the buy-out price, in some way, obliges to the Office of Gas and Electricity Markets to analyse the performance of the renewable obligation certificate market every year and set out the buy-out price for the incoming obligation period. This annual update motives the obligated parts to meet their renewable obligation certificates on time and avoid late payments because of the non-fulfilment of obligation. By the period 2002-2003, the proportion of late payments was 41.1% of the total obligation, and 0.1% by the period 2015-2016 (OFGEM 2017c). The Office of Gas and Electricity Markets (People/Institutions) evaluates the performance of the market annually in order to set the buy-out price (Processes/Procedures) (principle 16). It will be an important assessment to be considered by the Mexican authorities to enhance year by year the proportion between the obligations met and penalty fees.

4.2.3.3 Wind potential (c)[9]

Similarly to the United Kingdom wind potential, Mexico accounts for an important wind potential. It is also the second potential in importance in Mexico with a minimum scale of exploitation. Certainly, the key for the success of the renewable obligation certificate market implemented in the United Kingdom has been relied on the wind energy potential. This means that 54 million of renewable obligation certificates were issued in the period of 2015-2016, representing the 60% of the renewable share of certificates issued. Besides, the continuous efforts by authorities to remain a significant increase, the wind power is the sixth-largest in terms of installed capacity with 14.5 GWh (GWEC 2017). The Office of Gas and Electricity Markets (People/Institutions) sets out the renewable obligation (Goals) every year (principles 3, 7, 16). It remarks the recurring need for a constant supervision and attention to the clean energy certificate market behaviour by the Mexican authorities in order to amend the regulatory framework appropriately when necessary.

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[8] (b) This best practice can be found in Figure 4. 3 and in Table 4. 6 for analytical and comparative support, respectively.
[9] (c) This best practice can be found in Figure 4. 3 and in Table 4. 6 for analytical and comparative support, respectively.

4.2.4 Failures and comparisons with the Mexican CEC

4.2.4.1 Early closure market (d)[10]

The Government of the United Kingdom announced in 2015, the early closure of the renewable obligation scheme for onshore wind by April 2016, after a controversial discussion of the authorities for raising the flexibility and exemptions, these last efforts were in vain (Commons 2016). Resulting in a reduced amount of onshore wind capacity ahead due to early closure arrangements. In the same way, offshore wind was closed to renewable obligations, the closure deadlines were the underlying reason for a significant number of offshore projects were not able to enter it.

There is also, however, a further point to be considered, that consists in the onshore wind delivery between the closure of the renewable obligation certificate market and the new Contract for Difference (CfD) scheme, which are mostly due to being delivered in 2018 (GWEC 2016b). The United Kingdom government (People/Institutions) modified the sunset clause of the renewable obligation certificate market (Processes/Procedures), affecting some stakeholders (principles 15, 19). It has to be considered by the Mexican policymakers when the amendment of regulations has to be made, without hampering the continuous deployment of renewable energies.

4.2.4.2 Lack of attention to RES (e)[11]

In spite of the fact that the United Kingdom market has been one of the most relevant markets in the world, owing to the numerous and constant reforms amended to the renewable obligation certificate market regulations. The rate of growth in the generation of electricity from waste, was insignificant in comparison to others renewables sources. For instance, within the period from the launch of the renewable obligation certificate market in 2002 to 2015, the tremendous rate of growth for wind energy in that period was 3,109%, whereas for waste was 69% (IEA 2017k; IEA 2017m). This is an important difference considering the difference between these rates of growth in accordance with the quantity of amendments made by policymakers in the United Kingdom (People/Institutions), this implies an evident lack of attention to particular renewable energy sources (Technology), focusing their efforts on only a few ones (principles 1, 16).

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[10] (d) This failure can be found in Figure 4. 3 and in Table 4. 6 for analytical and comparative support, respectively.
[11] (e) This failure can be found in Figure 4. 3 and in Table 4. 6 for analytical and comparative support, respectively.

4.3 Australia

4.3.1 CEC market in Australia

4.3.1.1 Level of experience and clean energy targets

Australia was the first country in the world to implement a renewable energy certificate market in 2001, in accordance with the Mandatory Renewable Energy Target (MRET) enacted in the Renewable Energy (Electricity) Act 2000. This act stipulates a demand for electricity produced from renewable energies (Parliament of Australia 2014). Later, in the Renewable Energy (Electricity) Amendment Act 2009 was enacted a new renewable energy target of 23.5% or 33 TWh by 2020 (Clean Energy Regulator 2016a).

4.3.1.2 CEC trading

Accordingly to the Renewable Energy (Electricity) Act 2000, the power stations, owners of small-scale systems and wholesale purchasers are eligible to receive renewable energy certificates for 15 years. Afterwards, in the Renewable Energy (Electricity) Amendment Act 2010 was enacted a split into small-scale technology and large-scale generation entities, as well as separate renewable energy obligations for each of them. Correspondingly, the large-scale generation entities will reach the greater proportion of the renewable energy target in 2020 through large wind, solar, and geothermal energy projects (IEA 2012b).

4.3.1.3 Renewable Purchase Obligation (RPO) target and monitoring system or platform of CEC market

In Australia, the renewable power obligation is 7.01% for the small-scale technology and 14.22% for the large-scale generation in 2017, this obligation percentage is set out annually on 31 March by the Clean Energy Regulator (Office of Parliamentary Counsel 2017). These renewable obligations are registered in a monitoring platform of the renewable energy certificate market named “REC Registry”, administrated by AusRegistry International on behalf of the Clean Energy Regulator. The REC Registry system allows users to create, transfer and surrender renewable energy certificates as well as access to information concerning to the market (Clean Energy Regulator 2017e).

4.3.1.4 CEC market regulatory authority

The regulatory authority of the renewable energy certificate market is the Clean Energy Regulator, who is an Australian Government body in charge of the National Greenhouse and Energy Reporting Scheme, Renewable Energy Target and the Emissions Reduction Fund with the aim to reduce the carbon emission. The functions and powers of the Clean Energy Regulator are conferred by a climate change law and the national electricity law (Office of Parliamentary Counsel 2016).

4.3.1.5 Determination of CEC price, classification and denomination of CEC

The small-scale technology certificate price is determined by supply and demand, according to the movement of the price every day in the renewable energy certificate market operations (Clean Energy Regulator 2017b). In the same way, the large-scale generation certificate price is determined depending on supply and demand (Clean Energy Regulator 2017a). The renewable energy certificate market works under a technology-neutral scheme from July 2015, where the eligible renewable technologies are wind energy, hydropower, solar energy, geothermal-aquifer energy and bioenergy (Counsel 2016).

The small-scale technology certificates were created to support households, community groups and small businesses to install solar PV, wind turbines, hydro systems, solar water heaters and air source heat pumps. Therefore, one small-technology certificate is issued for each megawatt-hour (MWh). From the period 2009-2010 to the period 2014-2015 a multiplier for certificates was applied, this additional incentive started from 5 certificates in 2009-2010 to 2 certificates in 2014-2015 (Table 4. 3). Equally, one large-scale generation certificate is issued for each megawatt-hour (MWh) generated from eligible renewable sources (Counsel 2016).

Table 4. 3: Multiplier for certificates for small generation units

Period	Number
9 June 2009 to 30 June 2010	5
1 July 2010 to 30 June 2011	5
1 July 2011 to 30 June 2012	5
1 July 2012 to 30 June 2013	4
1 July 2013 to 30 June 2014	3
1 July 2014 to 30 June 2015	2

Source: (Counsel 2016)

4.3.1.6 Shelf life of CEC and sunset clause of CEC market

The small-scale technology certificates generated by hydro, solar PV or wind energy used to have a shelf life of 15 years until 2016. From 2017 these certificates will be reduced one year after a year, until the closure of the market in 2030 (Table 4. 4) (Clean Energy Regulator 2017c); the small-scale technology certificates generated by solar water heater or heat pump have a shelf life of 10 years (Clean Energy Regulator 2017g). Nevertheless, the large-scale generation certificates have a shelf life until they are cancelled (Clean Energy Regulator 2017d). Lastly, the sunset clause of the Australian renewable energy certificate market is by 01 January 2031 (Counsel 2016).

Table 4. 4: Solar PV Deeming Period in years

Year solar (PV) system installed	Deeming Period in years
before 2016	15
2016	15
2017	14
2018	13
2019	12
2020	11
2021	10
2022	9
2023	8
2024	7
2025	6
2026	5
2027	4
2028	3
2029	2
2030	1

Source: (Clean Energy Regulator 2017c)

4.3.1.7 Penalty scheme

In case of non-compliance of the renewable obligation by the liable entities, a shortfall charge of $65 AUD per MWh ($51.12 USD) must be paid by the obligated entities who do not surrender or purchase enough small-scale certificates (Parliament of Australia 2010) or large-scale generation certificates (Office of Legislative Drafting and Publishing 2011).

4.3.2 Market analysis

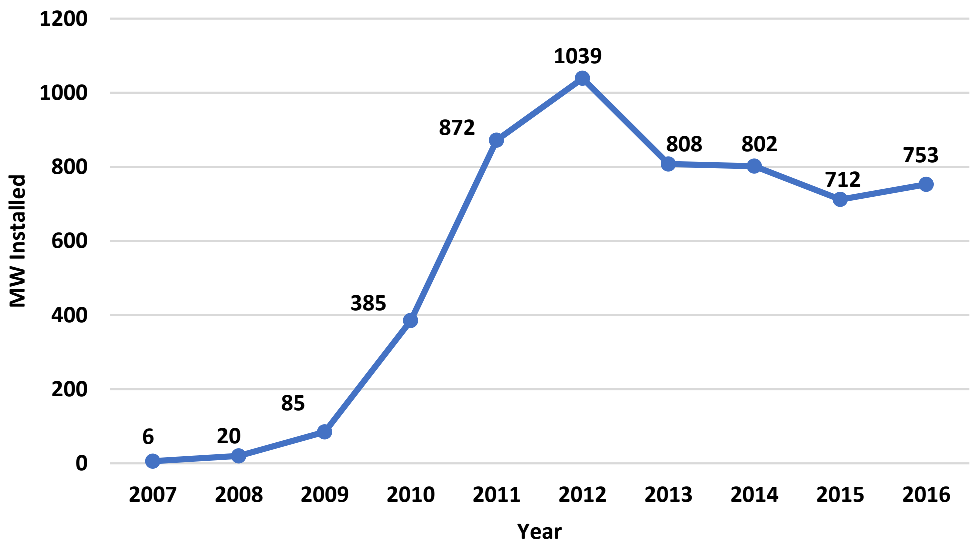
Australia was the first country to implement a renewable energy certificate market in the world in 2001. It is considered one of the most successful market, due to its clean energy targets have been reached and overpassed (IMCO 2015). In 2016, the total electricity generation share from renewable sources was 17.3%, this implies an important progress in comparison to the preceding year with a share of 14.6% from renewables, as a consequence of a growth in rainfalls, increased the hydropower electricity production in a 26% (Clean Energy Council 2017).

A significant factor in the Australian renewable energy certificate market was the separation of the liable entities into the Small-scale Renewable Energy Scheme (SRES) and the Large-scale Renewable Energy Target (LRET) from January 2011. In addition, the Large-scale Renewable Energy Target (LRET) was capped at 33 TWh by 2020, whereas for the Small-scale Renewable Energy Scheme (SRES) was not defined a target (Council 2016).

Certainly, a total of 17.5 TWh of renewable electricity was produced under the Large-scale Renewable Energy Target (LRET) throughout 2016; this amount represents approximately the 53% of the 33 TWh total target by 2020; also, it must be considered the new renewable energy projects under construction for 2017, adding close half of the remaining 14.5 TWh towards reaching the target (Clean Energy Council 2017).

On the other hand, the Small-scale Renewable Energy Scheme (SRES) encompasses the small-scale solar energy systems, which received certificates over 15 years and one small-scale technology certificate for each MWh of electricity generated, plus the application of a Solar Credit Multiplier (Figure 4.3) that compensated up to 5 certificates per 1 MWh generated (NREL 2017). It was fundamental for deploying solar energy systems in Australia, from 111 MW of total cumulative installed capacity in 2009 to 5,482 MW in 2016 (Figure 4. 4) (Clean Energy Council 2017).

Figure 4. 4: Annual Installed Capacity of Solar PV (MW)



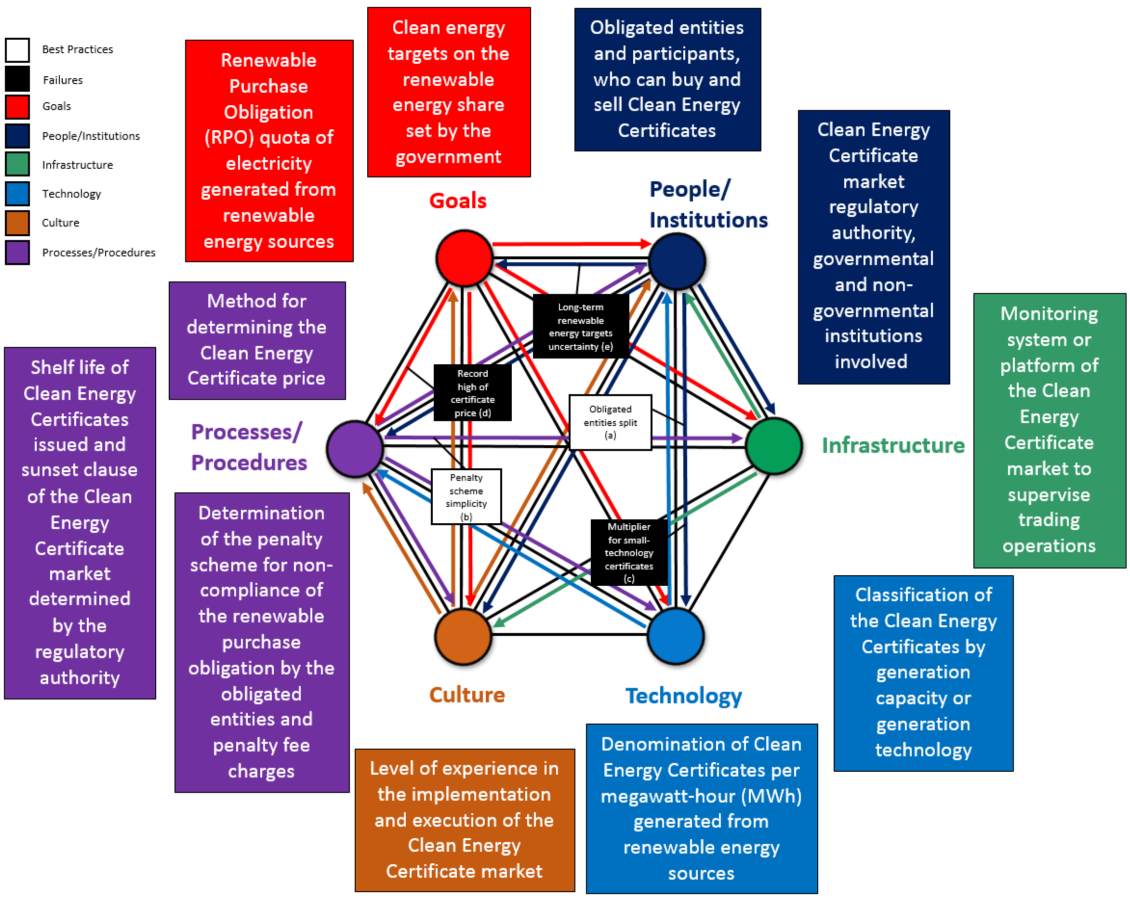
Source: (Clean Energy Council 2017)

Since the implementation of the renewable energy certificate market in 2001, the wind energy projects have had the largest electricity generation share from renewable sources with around 70% from 2001 to 2015, and solar energy projects with 4.6%. These technologies have taken advantage of the Australian renewable energy target scheme (NREL 2017).

The renewable energy certificate market implementation in Australia has been an important support for electricity generation from renewable sources due to the financing and construction of large-scale and small-scale renewable energy projects. In addition, the certainty for investors that the certificate market offers through long-term contracts. However, the experience of other countries in order to improve the project sponsorships could be helpful for the Australian market to make a wider range of opportunities and innovations (Clean Energy Regulator 2016c).

4.3.2.1 Analysis from the socio-technical perspective

Figure 4. 5: Analysis from the socio-technical perspective of the Australian CEC market



4.3.3 Best practices and comparisons with the Mexican CEC

4.3.3.1 Obligated entities split (a)[12]

In 2010, the renewable energy certificate market of Australia was split into small-technology certificates and large-scale generation certificates in order to support individuals or small businesses with a financial incentive to install small-scale renewable energy systems (Clean Energy Regulator 2017f). This split aimed to increase the installed capacity of solar PV from 111 MW in 2009 to 5,482 MW in 2016 (Clean Energy Council 2017). The Australian government (People/Institutions) decided to split the market (Technology), designing an optimal scheme for a greater participation of the obligated entities (principles 3, 7). This suggests that the clean energy certificate market of Mexico could adopt the separation between the small and large electricity producers to boost the amount of the installed capacity solar PV, taking advantage of the solar potential in Mexico.

4.3.3.2 Penalty scheme simplicity (b)[13]

Evidence for success of the Australian renewable energy certificate market can be found in the high rates of compliance by liable entities. Firstly, the small-scale technology certificates surrendered were 20 586 873, representing a 99.9% of compliance in the period 2015. Secondly, the large-scale generation certificates surrendered were 19 175 716, representing a 99.4% of compliance in the same period (Clean Energy Regulator 2016a).

The simplicity of the penalty scheme has been an aid for the certificates liability discharge for liable entities who do not surrender or purchase enough certificates. The small-scale technology entities and large-scale generation entities are regulated under the same penalty scheme, in case of non-compliance obligation and must pay a high penalty fee of $51 USD which is not a tax-deductible expense (Clean Energy Regulator 2017f). A simple penalty scheme design (Processes/Procedures) has eased the REC Registry system (Infrastructure) the task of the certificates surrender process (principles 11, 13). In comparison to the Mexican penalty scheme, where a sanction matrix with 24 different options is established from very low to very high penalty fees to be paid by the obligated entities.

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[12] (a) This best practice can be found in Figure 4. 5 and in Table 4. 6 for analytical and comparative support, respectively.

[13] (b) This best practice can be found in Figure 4. 5 and in Table 4. 6 for analytical and comparative support, respectively.

4.3.4 Failures

4.3.4.1 Multiplier for small-technology certificates (c)[14]

The implementation of solar credit multipliers for the small-technology certificates scheme to support owners with an up-front cost reduction for solar energy systems, resulted in a substantial quantity of certificates in the market, owing to the contribution of energy systems like the solar water heaters or the heat pumps in households (Chapman, McLellan and Tezuka 2016). The multiplier effect caused a dramatic decrease in certificate prices of $23 USD, as a consequence from this, a fixed price of $32 USD was set by the Australian government and the multiplier was removed six months before the deadline. (NREL 2017). The Australian government (People/Institutions) controlled the effects caused to the small-technology certificates market (Technology) (principle 12).

The excess of incentives for particular renewable sources can lead to hamper the development of these technologies rather than increase their use and depress the renewable energy certificate price.

4.3.4.2 Record high of certificate price (d)[15]

In spite of the positive installed capacity growth of renewable energy sources in Australia from the launch of the renewable energy certificate market in 2001, the large-scale generation certificate price in the spot market reached a record high of $66 USD in the period 2015-2016, when the ranged price was $40 USD (Clean Energy Regulator 2016b). Evidently, this peak in the spot certificate price was because of the shortage of large-scale generation certificates, due to the renewable energy generated was not enough to meet the obligations (Goals) through the surrendering of certificates and like any spot market, the supply and demand caused this record high of large-scale generation certificates (Processes/Procedures) (principle 17).

Assuming the experience and success of the Australian renewable energy certificate market, the efforts are not never sufficient in order to maintain the stability and growth of the renewable energy certificate market.

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[14] (c) This failure can be found in Figure 4. 5 and in Table 4. 6 for analytical and comparative support, respectively.

[15] (d) This failure can be found in Figure 4. 5 and in Table 4. 6 for analytical and comparative support, respectively.

4.3.4.3 Long-term renewable energy targets uncertainty (e)[16]

The lack of a long-term renewable energy target that faces the Australian market, due to the peak in the renewable energy target of 33,850 GWh in 2020 and the plateau until 2030 (Counsel 2016). For this reason, the projects further than 2030 have been hampered because of the long-term recovery of investment cost. There is also, however, a further point to be considered within renewable energy target, which ought to rise after 2020 in order to decrease the uncertainty of current power stations (People/Institutions) and new long-term projects in the future (Goals) (principles 3, 4, 7) (Clean Energy Council 2016).

4.4 India

4.4.1 CEC market in India

4.4.1.1 Level of experience and clean energy targets

According to the Indian National Action Plan for Climate Change (NAPCC), the renewable energy certificate market was launched in 2010 by the Indian Ministry of Power in order to tackle the climate change and energy security issues, as well as the transition to low-carbon technologies use and greenhouse gas emissions reduction (Gupta and Purohit 2013). Likewise, the Indian National Action Plan for Climate Change (NAPCC) established a target of 15% of the energy share from renewables by 2020 (India 2008).

4.4.1.2 CEC trading and Renewable Purchase Obligation (RPO) target

The Central Electricity Regulatory Commission (CERC) considers the distribution licensees, open access consumers and captive power plant (CPP) as eligible entities to receive renewable energy certificates (Kumar and Agarwala 2013b). Similarly, the renewable purchase obligations are mandated by each State Electricity Regulatory Commission (SERC), based on the availability of resources in the states. The renewable purchase obligations are set for a maximum period of 3 to 5 years (Table 4. 5) (Chatterjee, Dwivedi and Sengupta 2014).

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[16] (e) This failure can be found in Figure 4. 5 and in Table 4. 6 for analytical and comparative support, respectively.

Table 4. 5: RPO across states

States	2010–11	2011–12	2012–13	2013–14	2014–15	2015–16
Andhra Pradesh	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%
Assam	1.40%	2.80%	4.20%	5.60%	7.00%	
Bihar	1.50%	2.50%	4.00%	4.50%	5.00%	
Chhattisgarh	5.00%	5.25%	5.75%			
Delhi	2.00%	3.40%	4.80%	6.20%	7.60%	9.00%
Goa & UT	1.00%	2.00%	3.00%			
Gujarat	5.00%	6.00%	7.00%			
Haryana	1.50%	2.00%	3.00%			
Himachal Pradesh	10.01%	10.01%	10.25%	10.25%	10.25%	10.25%
Jammu & Kashmir	1.00%	3.00%	5.00%			
Jharkhand	2.00%	2.50%	3.10%			
Karnataka	0.25%	0.25%	7.25%	7.25%	7.25%	7.25%
Kerala	5.25%	5.25%	5.25%	5.25%	5.25%	5.25%
Madhya Pradesh	0.80%	2.50%	4.00%	5.50%	7.00%	
Maharashtra	6.00%	7.00%	8.00%	9.00%	9.00%	9.00%
Manipur	2.00%	3.00%	5.00%			
Mizoram	5.00%	6.00%	7.00%			
Meghalaya	0.50%	0.75%	1.00%			
Nagaland	6.00%	7.00%	8.00%			
Orissa	5.00%	5.00%	5.50%	6.00%	6.50%	7.00%
Punjab	2.40%	2.86%	3.44%	3.94%	4.00%	
Rajasthan	8.50%	9.50%	7.10%	8.20%		
Tamil Nadu	10.15%	9.05%				
Tripura	1.00%	1.00%	2.00%			
Uttarakhand	10.00%	11.00%				
Uttar Pradesh	4.00%	5.00%	6.00%			
West Bengal	2.00%	3.00%	4.00%			

Source: (Gupta and Purohit 2013)

4.4.1.3 Monitoring system or platform of CEC market and CEC market regulatory authority

The National Load Despatch Centre (NLDC) is the nodal agency that registers, issues, redeems, and settles the renewable energy certificates through the online system “Renewable Energy Certificate Registry of India”. The renewable energy certificates issued can be traded in Indian Energy Exchange Limited (IEX) and Power Exchange India Limited (PXIL). These power exchanges were previously approved by the Central Electricity Regulatory Commission (CERC) (Shrimali and Tirumalachetty 2013). This authority was created by the Ministry of Power as a statutory body to regulate the Indian power sector and outlined the renewable energy framework. The State Electricity Regulatory Commission (SERC) determines the renewable purchase obligations in each state of India. In this way, the State Agency is in charge of the obligated entities accreditation and the Central Agency registers the obligated entities and issues the renewable energy certificates (CERC 2015).

4.4.1.4 Determination of CEC price

The Central Electricity Regulatory Commission (CERC) proposed forbearance and floor prices for solar and non-solar certificates to avoid the price volatility and protect consumers and generators (Shrimali and Tirumalachetty 2013). The renewable energy certificate price is determined by supply and demand in power exchange within the forbearance price and floor price range. The non-solar certificate prices are: forbearance price Rs 3,000 ($46 USD) and floor price Rs 1,000 ($15 USD); and the solar certificate prices are: forbearance price Rs 2,400 ($37 USD) and floor price Rs 1,000 ($15 USD); these prices are applicable from April 2017 (POSOCO 2017).

4.4.1.5 Classification and denomination of CEC

The Indian renewable energy certificate market works under a technology-neutral scheme, where the renewable sources eligible for certificates are wind energy, small hydropower, bioenergy, and solar energy (CERC 2015). Therefore, one renewable energy certificate is issued for each megawatt-hour (MWh) from an eligible renewable source. Thus, the Central Electricity Regulatory Commission (CERC) has specified the renewable energy certificates in two categories: solar and non-solar certificates (Shrimali and Tirumalachetty 2013).

4.4.1.6 Shelf life of CEC and sunset clause of CEC market and penalty scheme

Accordingly to the certificate market regulatory framework, the shelf life for solar and non-solar renewable energy certificates have a shelf life of 3 years. On the contrary, the sunset clause of the renewable energy certificate market has not been defined yet. However, when a renewable purchase obligation is not met, a penalty fee must be paid at forbearance price by the obligated participants: for a non-solar certificate shortfall is Rs 3,000 ($46 USD) and for a solar certificate shortfall is Rs 2,400 ($37 USD) (POSOCO 2017).

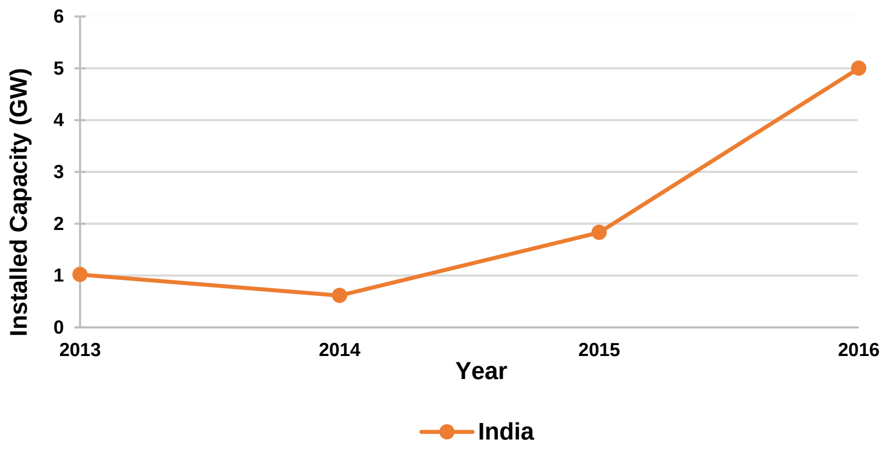
4.4.2 Market analysis

The launch of the Indian renewable energy certificate market was in 2010, as a measure to mitigate the global warming and climate change implemented by the Central Electricity Regulatory Commission (CERC), alongside to the Jawaharlal Nehru National Solar Mission (Kumar and Agarwala 2013b).

India accounts with natural resources for renewable energy generation, such as solar, wind, biomass and hydropower. It is worth noting that the highest resource potential in India is the solar energy potential with 5,000 trillion kWh per year. This solar potential is translated to solar thermal and solar PV for clean energy generation through the implementation of government incentives. For instance, the Solar Mission has launched a target of 20,000 MW in three phases, 2012-2013, 2013-2017 and 2017-2022 with grid connected solar energy included (Kumar and Agarwala 2013a).

Globally, India has an important role in solar PV installed capacity. In 2016, the Indian installed capacity added was 5 GW, becoming the fourth-largest in the world, just after China, USA, and Japan with 34.5 GW, 14.5 GW and 10.2 GW, respectively (Figure 4. 6). In 2017, there is an expected new capacity addition around 8.8 GW, representing an increase of 76% in comparison with the preceding year, and will make India the third-largest in the world. Currently, approximately 12.4 GW of solar energy projects are under execution throughout 2017 (India 2017).

Figure 4. 6: Solar PV capacity addition in the Indian market



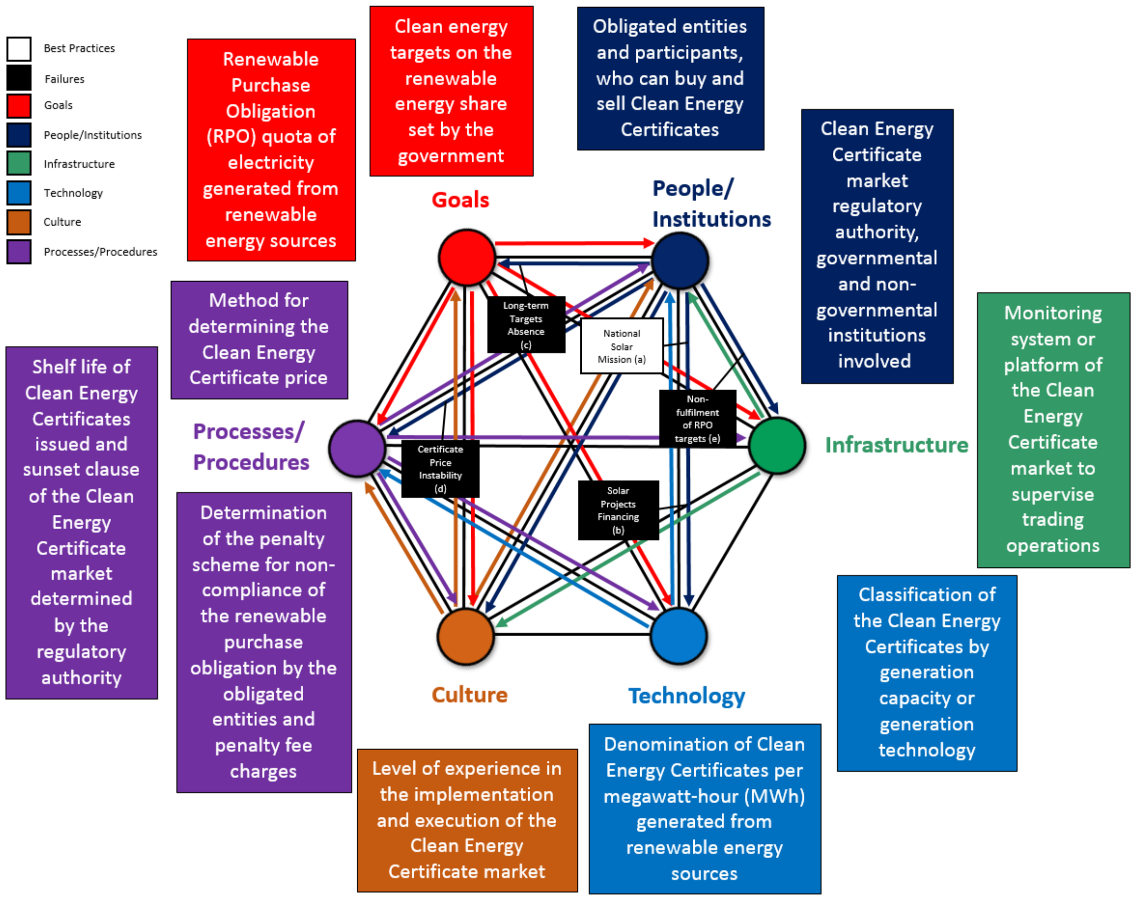
Source: (India 2017)

In the beginning of the renewable energy certificate market implementation in India, the certificates were available for trading up to 365 days once issued (Kumar and Agarwala 2013a). The Central Electricity Regulatory Commission (CERC) has amended the validity of certificates to be 1,095 days (3 years) (POSOCO 2017), as an economic key in terms of certificate price volatility reduction (Chatterjee, Dwivedi and Sengupta 2014).

The aim of the renewable purchase obligation has tried to rise the use of renewable sources for electricity generation in states with abundant natural resources as solar radiation, wind or biofuel potential, and trade renewable energy certificates with states with low potential. But, the fulfilment of the renewable targets by states has been low, as a consequence of this, the supply has overpassed the demand of renewable energy certificates, as well as the stock of unsold certificates has increased. It follows that the forecast for the Indian certificate market is not optimal for current and future renewable energy generators (IRENA 2017).

4.4.2.1 Analysis from the socio-technical perspective

Figure 4. 7: Analysis from the socio-technical perspective of the Indian CEC market



4.4.3 Best Practices

4.4.3.1 National Solar Mission (a)[17]

One of the main aims of the Indian National Action Plan for Climate Change (NAPCC) in 2008, was the objective of exploit the solar resources of India for power generation from renewables with an installed capacity of 100 GW by 2022 (Sahoo 2016). It was based on the world's largest solar energy potential with around 5000 trillion kWh per

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[17] (a) This best practice can be found in Figure 4. 7 and in Table 4. 6 for analytical and comparative support, respectively.

year (Rohankar *et al.* 2016). The Jawaharlal Nehru National Solar Mission or National Solar Mission was created by the Government of India through the Ministry of New and Renewable Energy (People/Institutions), becoming a fundamental support for the renewable energy certificate market in order to enforce the deployment of renewable energy sources, in particular for solar PV technologies (Technology) (principles 4, 7) (MNRE 2017).

4.4.4 Failures

4.4.4.1 Solar projects financing (b)[18]

In spite of the significant solar potential in India and the growth of solar installations in recent years, the renewable energy certificate market has been affected by the lack of solar projects financing support. It was caused by the high interest rates and the instability in the capital markets. Besides, the domestic financial scheme is expensive and is only available for short-term, as well as the distribution companies are not competitive. It is however, important to note the limitations of the Indian financial institutions and the lack of attention of the Indian policymakers (People/Institutions), in order to incentive the long-term solar PV projects (Technology) through attractive financial schemes as a complement of the implementation of the renewable certificate market (principles 12, 18) (Kar, Sharma and Roy 2016).

4.4.4.2 Long-term targets absence (c)[19]

In accordance with the regulatory framework of the renewable energy certificate market in India, each state (People/Institutions) determines their own renewable purchase obligation for a maximum period of 3 to 5 years (Goals); resulting from this in a poorly attractive market for long-term project investors and the creation of uncertainty in the shelf life of the market (principles 1, 4, 10). It makes impossible the long-term project evaluation by investors, increasing the risk of adding new renewable energy generation capacity. In addition, with the absence of long-term targets is unlike to estimate the performance of the renewable certificate market in terms of prices, supply and demand of certificates (Shrimali and Tirumalachetty 2013).

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[18] (b) This failure can be found in Figure 4. 7 and in Table 4. 6 for analytical and comparative support, respectively.

[19] (c) This failure can be found in Figure 4. 7 and in Table 4. 6 for analytical and comparative support, respectively.

4.4.4.3 Certificate price instability (d)[20]

As a result of the Indian solar potential, the Central Electricity Regulatory Commission (People/Institutions) determined two categories for the renewable energy certificates in solar and non-solar certificates to encourage the deployment of solar power. Equally, forbearance and floor prices (Processes/Procedures) are specified by the regulatory authority for each certificate category (principles 3, 5, 12, 16). Lastly, the renewable purchase obligations are not similar in all states, causing significant differences of generated energy in each state and the number of tradable certificates (Rohankar *et al.* 2016). For these reasons, an instability in the certificate price has decreased for solar and non-solar certificates from $195 UDS and $33 USD in 2012 to $53 USD and $23 UDS in 2016, respectively (IEX 2017).

4.4.4.4 Non-fulfilment of RPO targets (e)[21]

It is important to note, however, the limitations of the renewable energy certificate market in India because of the absence of a constant trend in the compliance of renewable purchase obligations defined by states (People/Institutions). Most of them have not been fulfilled both solar and non-solar targets. In some cases, the obligated entities surrender solar certificates with non-solar certificates. Hence, the implementation of a framework (Infrastructure) for supervising the renewables purchase obligations compliance is necessary to foster the use of renewable sources; in order to monitor the fulfilment of the targets in shorter periods of time than one year. In this manner, the regulatory authorities can make decisions on time to enforce the renewable purchase obligations compliance (principles 3, 4, 10, 18) (Shakti 2014).

4.5 California

4.5.1 CEC market in California

4.5.1.1 Level of experience and clean energy targets

The Californian Legislature enacted in the Senate Bill 1078 the Renewable Energy Certificate or Credit Market under the Renewable Portfolio Standard (RPS) in 2002

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[20] (d) This failure can be found in Figure 4. 7 and in Table 4. 6 for analytical and comparative support, respectively.

[21] (e) This failure can be found in Figure 4. 7 and in Table 4. 6 for analytical and comparative support, respectively.

(CPUC 2006). The executive order S-21-09 signed in 2009 by the Governor of the State of California outlined a renewable target of 33% or 75 TWh by 2020 (Nexant 2009) and allowed the electricity trade with the participant states of the Western Interconnection (C2ES 2017).

4.5.1.2 CEC trading and Renewable Purchase Obligation (RPO) target

The California Energy Commission defined as obligated entities to the electricity producers, electricity service providers, investor-owned utilities, publicly owned utilities, and community choice aggregators, under the Renewable Portfolio Standard (IEA 2014). Equally, the renewable purchase obligation for the obligated entities is determined in the executive order S-21-09 with 29% of the renewable energy share for 2018, with an increasing rate of 2% each year until 2020 (State of California 2017b).

4.5.1.3 Monitoring system or platform of CEC market and CEC market regulatory authority

The monitoring system in charge of the renewable energy certificate operations tracking is the Western Renewable Energy Generation Information System or WREGIS. This monitoring system is operated by the Western Electricity Coordinating Council or WECC, under the supervision of the California Energy Commission (Commission 2017d), which is the regulatory authority of the renewable energy market. This authority is the primary energy policy and planning agency of the State of California. Likewise, this agency uses its power to reduce the energy cost and the environmental impacts with a supply of energy in a safe, resilient and reliable way (Commission 2017a).

4.5.1.4 Determination of CEC price and classification of CEC

The price of renewable energy certificates is determined by supply and demand. A price cap of $50 USD per certificate has been set to mitigate the price volatility. In case of a obligated entity pays more than the price cap, it cannot be used for Renewable Portfolio Standard compliance, this mechanism was determined by the California Energy Commission in 2013 (Shakti 2014). The renewable energy certificate market works under a technology-neutral scheme, which the eligible renewable energy sources are wind, geothermal, small hydropower, solar, tidal current, ocean, bioenergy, and fuel cell using renewable fuel (Commission 2017c).

4.5.1.5 Denomination of CEC, shelf life of CEC and sunset clause of CEC market and penalty scheme

The Californian market establishes that one renewable energy certificate is issued for each megawatt-hour (MWh) of renewable energy generated in accordance with the eligible sources defined by the California Energy Commission (WECC 2016). The shelf life of the renewable energy certificates is 3 years to facilitate flexible rules for Renewable Portfolio Standard compliance. However, the sunset clause of the renewable energy certificate market has been defined until 2030 (Scientists 2016). Lastly, the penalty fee for Renewable Portfolio Standard non-compliance is $50 USD per MWh, up to $25 USD million per year per entity (Shakti 2014).

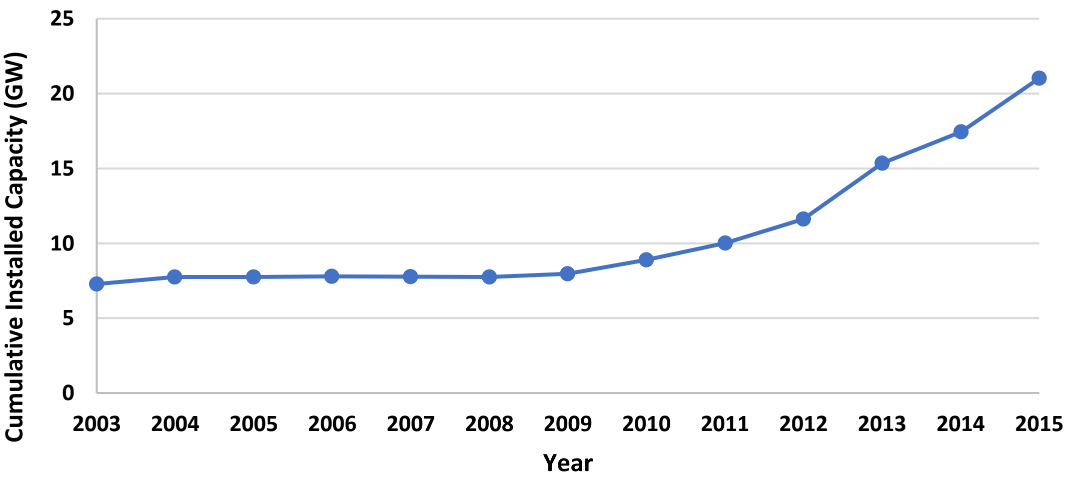
4.5.2 Market analysis

The Californian renewable energy certificate market was one of the first markets in the world, launched in 2002, and also, one of the most successful certificate market. There are several characteristics that the State of California faces, such as the most populated state and the largest economy in the United States. Besides, it is the second state in terms of total energy demand (EIA 2017). California is the leader in electricity produced from renewable sources like biomass, geothermal and solar energy, and the fourth electricity producer from hydropower and wind energy. In 2014, California was the first state in produce electricity from solar energy in more than 5% (EIA 2017).

California has become a worldwide leader in renewable energy, resulting from this, in the attraction of billions of dollars to industrial investment in clean technology generation sources, and a significant reduction of greenhouse gases and pollutants emissions. The Californian renewable energy certificate market has helped the State of California to take advantage of its renewable energy resources in order to exploit them widely (Scientists 2016).

The State of California has set an ambitious target of 50% in the renewable share of electricity generation by 2030. This implies, a steady increase of the installed renewable generation capacity throughout the Californian certificate market life. It has generated certainty for hosting renewable projects, especially in recent years, the growth has increased dramatically (Figure 4. 8). Consequently, the amount of people directly or indirectly employed by the renewable energy generation industry has risen since the Renewables Portfolio Standard was enacted in 2002 (Scientists 2016).

Figure 4. 8: California Renewable Generation Capacity, 2003–2015



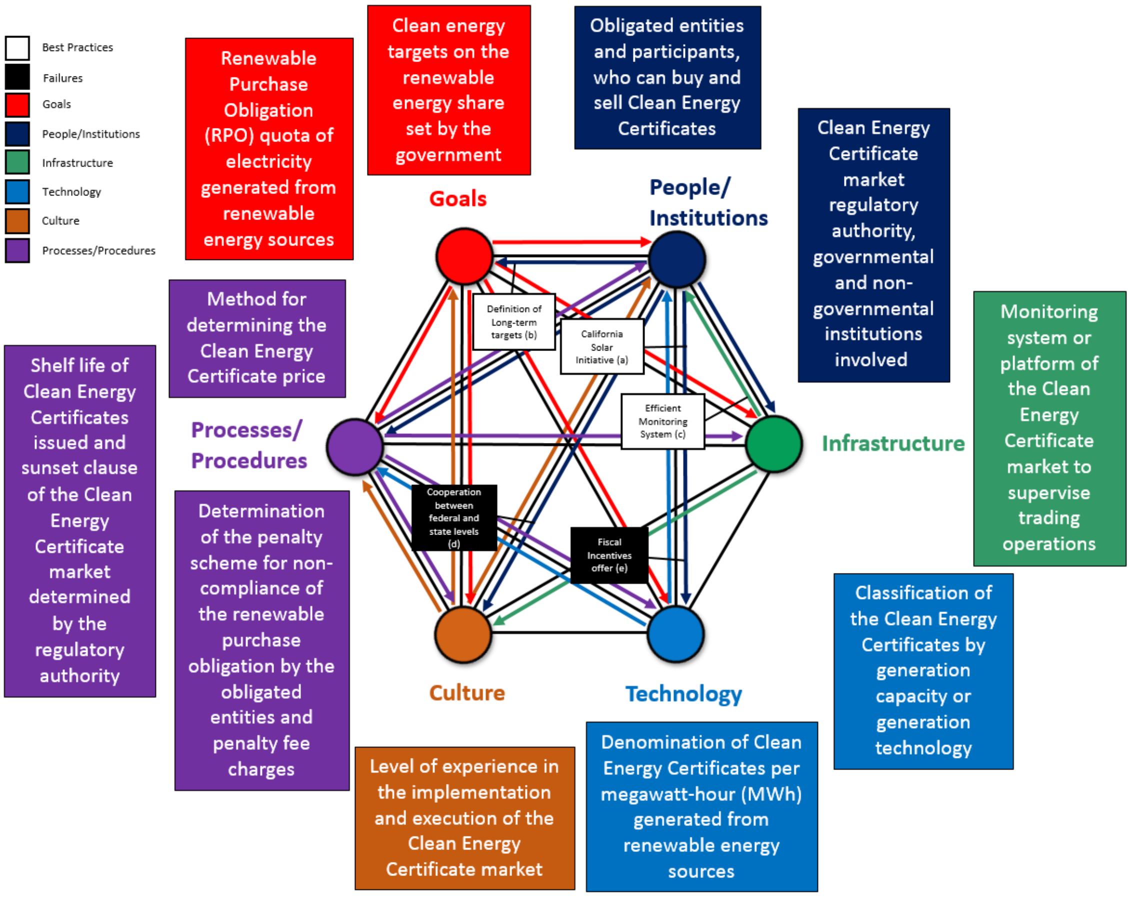
Source: (Scientists 2016)

The Californian solar PV market has grown extensively, adding new capacity every year. In 2015, the United States had a record year in solar PV installations with roughly 7.3 GW. California was the state with the largest capacity added with 3.3 GW; North Carolina ranked second with 1.1 GW and Hawaii in third place (REN21 2016). For 2016, the capacity added by the United States was 14.8 GW, where 5.1 GW were added by California, Utah 1.2 GW and Georgia 1 GW. As a result of the increment in recent years of solar PV installations and other renewables sources, the cities of San Diego and San Francisco in California have set a target of 100% to generate electricity from renewables by 2020 (REN21 2017).

The Californian market in the United States provides certainty to investors by setting ambitious long-term goals, it can be achieved by the reduction of the strategic accumulation action by making them valid for three years. It is reinforced with a robust and transparent registration system that monitors efficiently the compliance of the market commitments (IMCO 2015).

4.5.2.1 Analysis from the socio-technical perspective

Figure 4. 9: Analysis from the socio-technical perspective of the Californian CEC market



4.5.3 Best Practices and comparisons with the Mexican CEC

4.5.3.1 California Solar Initiative (a)[22]

Alongside the implementation of the renewable energy certificate market, the State of California through the California Public Utilities Commission (People/Institutions) created the California Solar Initiative (CSI) rebate programme, which is part of the Go Solar California campaign. This programme consists of different subsidies for customers to install energy solar systems (Technology) and sell the surplus of the generated electricity (principles 4, 7, 10). For instance, this programme funds solar PV installations, solar hot water systems and RD&D of solar technologies (State of California 2017a). The first stage of the programme started in 2007 and ended in 2017. However, the

[22] (a) This best practice can be found in Figure 4. 9 and in Table 4. 6 for analytical and comparative support, respectively.

extension of this programme is being considered by the regulatory authority because of the success of this solar initiative and the established long-term target in the greenhouse gases emission abatement of 80% by 2050 (Commission 2017e).

4.5.3.2 Definition of long-term targets (b)[23]

The Renewable Portfolio Standard programme was launched in 2002, where the renewable market certificate market was included with the goal of 20% in the electricity generation mix from renewable sources by 2017. One year later, in 2003, the Californian Government (People/Institutions) amended the goal of 20% by 2010. However, a more ambitious goal was established in 2004, this time, a long-term target of 33% by 2020 (Goals). Following this amendment of renewable targets and the favourable tendency in the growth of renewable installed capacity in California, a goal of 25% in retail sales was defined by 2016 (IRENA 2015).

It can be seen from the above analysis that, based on the experience of the Californian renewable energy certificate market. This may be applied in the Mexican market, in terms of the amendment and definition of long-term renewable targets, which may increase the certainty to investors in order to develop large-scale projects and incentive the boost of clean technologies (principles 1, 6).

4.5.3.3 Efficient monitoring system (c)[24]

The efficiency of a monitoring system for a renewable energy certificate market, plays a fundamental role in the fulfilment of the renewable government targets, due to the interaction among stakeholders. The Californian renewable energy certificate market accounts with the Western Renewable Energy Generation Information System (WREGIS) (Infrastructure). This monitoring system is characterised for working as an independent banking system with permanent surveillance to issue, create and surrender renewable certificates in real time. It is worth noting that the information regarding to power plant type, generation capacity, and the amount of megawatt-hour generated per period is rigorously processed in order to avoid the double counting (People/Institutions) (principles 1, 14, 18) (Commission 2017d). The importance of the monitoring system performance in the Mexican certificate market will be a rationale for a satisfactory target compliance.

[23] (b) This best practice can be found in Figure 4. 9 and in Table 4. 6 for analytical and comparative support, respectively.
[24] (c) This best practice can be found in Figure 4. 9 and in Table 4. 6 for analytical and comparative support, respectively.

4.5.4 Failures

4.5.4.1 Cooperation between federal and state levels (d)[25]

Despite of the significant growth in the generation of electricity through the renewable energy certificate mechanism in California, there is a lack of cooperation between the federal and state levels (People/Institutions), such as the exchange of best practices. The enforcement of collaborative programmes (Culture) is needed for the transmission grid enhancement, in terms of increasing the number of renewable installed capacity in California and neighbouring states, generating the opportunity of creating an interstate renewable certificate market (principles 1, 2,19). In this way, California could be benefited from federal incentives for expanding and extending the deployment of renewables energies that are less developed to level the electricity generation mix from renewable sources (IEA 2014).

4.5.4.2 Fiscal incentives offer (e)[26]

The durability and predictability of subsidies and fiscal incentives by the Californian government have to be greater for renewable investors. In spite of the certainty of the long-term targets definition, it is important however not to overemphasis the strengths of the ambitious goals announced by the government of California (People/Institutions). At the same time, the collaboration with other important investors that generate energy from bioenergy and waste, can increase the electricity generation share of these renewable technologies (Technology) (IEA 2014). Thus, the diversification of renewables sources in electricity production could be more equilibrated (principles 4, 10, 16) (Commission 2017b).

4.6 Emphasising international best practices and failures

In this section are gathering the best practices and failures found in the evaluation of the countries according to the socio-technical system approach. Table 4. 6 is the comparison of the best practices and failures and Table 4. 7 is the summary of the best practices and failures.

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[25] (d) This failure can be found in Figure 4. 9 and in Table 4. 6 for analytical and comparative support, respectively.
[26] (e) This failure can be found in Figure 4. 9 and in Table 4. 6 for analytical and comparative support, respectively.

4.6.1 Comparison table of international CEC markets

In Table 4. 6 are included the design features defined for this research project with their descriptions for each country. These descriptions are followed by letters, which are linked to their market analysis narrative and to the socio-technical framework analysis, respectively. This table helps the reader visually to identify the best practices, neutrals and failures in an easy manner.

The descriptions are identified with different background colours that represent the best practices (white), neutrals (grey) and failures (black). These assignations were defined as a result of the evaluation made in this chapter previously. For a further explanation for the best practices and failures of the design features in this table, the letters are linked to the market analysis that can be found in the evaluation of each country in this chapter. It is worth noting that the assignation for neutrals was made to the rest of the design features that were not best practices nor failures.

Table 4. 6: Comparison table of international CEC markets

(white)	Best Practices
(grey)	Neutrals
(black)	Failures

Features	Sweden and Norway	UK	Australia	India	California	Mexico
Level of Experience	Sweden established the electricity certificate market since 2003, afterwards alongside Norway, created a joint market in 2012 (b)	The United Kingdom established a Renewable Obligation Certificate market in 2002	Australia implemented a renewable energy certificate market in 2001	India launched the Renewable Energy Certificate market in 2010	The Californian renewable energy certificate market was created in 2002 (d)	In 2018, Mexico will be launching the Clean Energy Certificate market operations
Clean energy target	The renewable energy target for Sweden is 49% and for Norway is 67.5% or 28.4 TWh, where Sweden will be responsible for 15.2 TWh and Norway for 13.2 TWh by 2020 (a)	The United Kingdom government has set a target of 15% of renewable energy share or 238 TWh by 2020	The Australian renewable energy target is 23.5% or 33 TWh by 2020 (e)	India established a target of 15% of the energy share from renewables by 2020 (c)	The Californian government set a renewable target of 33% or 75 TWh by 2020 (b)	The minimum electricity production target from renewable sources is 28.3% or 90.5 TWh by 2020 (a)
CEC Trading	The eligible entities to receive electricity certificates are the approved generation plants for 15 years	The obligated entities under the Renewable Obligation Certificate scheme are the electricity suppliers for over a	The power stations, owners of small-scale systems and wholesale purchasers are eligible to receive renewable energy	Distribution licensees, open access consumers and captive power plant (CPP) are eligible to receive renewable energy certificates (b)	The obligated entities are the electricity producers, electricity service providers, investor-owned utilities, publicly	Clean energy certificates can be issued for electricity producers established after August 11th 2014 or existing plants

Features	Sweden and Norway	UK	Australia	India	California	Mexico
		maximum of 20 years.	certificates for 15 years		owned utilities and community choice aggregators	who add electricity capacity production from renewables, and volunteer entities over a maximum 20 years
Renewable Purchase Obligation (RPO) target	27.0% Sweden and 15.4% Norway in 2018 with an increasing rate until 2020 of 28.8% and 19.7% respectively	The calculation of the obligation set out by Ofgem is 40.9% in England, Wales and Scotland and 16.7% in Northern Ireland, for the period from 1 April 2017 to 31 March 2018 (c)	The renewable power obligation is 7.01% for small-scale technology and 14.22% for large-scale generation in 2017	Each Indian state sets a renewable purchase obligation, which are within the range of 1.5% up to 10% (e)	The renewable purchase obligation is 29% in 2018, with an increasing rate of 2% each year until 2020	5.0% in 2018, 5.8% in 2019, 7.4% in 2020, 10.9% in 2021 and 13.9% in 2022 according to the Electricity Industry Law
Monitoring system or platform of CEC market	Cesar is operated by Energimyndigheten (Swedish Energy Agency), and NECS (Norwegian Energy Certificate System) is operated by Statnett	The “Renewables and CHP Register” system is operated by Ofgem E-Serve	The monitoring platform of the renewable energy certificate market is “REC Registry” administrated by AusRegistry International	The Indian online system is “Renewable Energy Certificate Registry of India”	The monitoring system is the Western Renewable Energy Generation Information System or WREGIS (c)	The Certificate Management and Clean Energy Compliance System (Sistema de Gestión de Certificados y Cumplimiento de Obligaciones de Energias Limpias, S-CEL) is in charge of the cancellation and sell of clean energy certificates

Features	Sweden and Norway	UK	Australia	India	California	Mexico
CEC Market regulatory authority	Swedish Energy Agency and Norwegian Water Resources and Energy Directorate (NVE)	The Office of Gas and Electricity Markets (Ofgem)	The Clean Energy Regulator	The Central Electricity Regulatory Commission (CERC)	The California Energy Commission (CEC)	The Energy Regulatory Commission (Comisión Reguladora de Energía CRE)
Determination of CEC price	The electricity certificate price is determined by supply and demand on an open market	The price of Renewable Obligation Certificates is determined by the supply and demand of the market	The renewable energy certificate price is determined by supply and demand in the both small-scale technology certificate and large-scale generation certificate markets (d)	The Renewable Energy Certificate price is determined by supply and demand in power exchange within the range of the forbearance price and floor price (d)	The price of renewable energy certificates is determined by supply and demand	The price of clean energy certificates is determined by supply and demand and is regulated by the National Centre for Energy Control.
Classification of CEC	Technology-neutral: • Wind energy • Solar energy • Hydropower • Geothermal energy • Biofuel (included peat in combined heat and power plants in Sweden) • Wave power (c)	Technology-banding: • Wind energy • Bioenergy power • Solar energy • Hydropower (a)	Technology-neutral: • Wind energy • Solar energy • Geothermal-aquifer energy • Hydropower • Bioenergy power (a)	Technology-neutral: • Wind Energy • Small Hydropower • Bioenergy • Solar energy (a)	Technology-neutral: • Wind energy • Geothermal energy • Small Hydropower • Solar energy • Tidal Current • Ocean energy • Bioenergy power • Fuel cell using renewable fuel (a)	Technology-neutral: • Wind energy • Solar energy • Hydropower • Geothermal energy • Nuclear power • Bioenergy power • Wave power (d)
Denomination of CEC	One electricity certificate is issued for each megawatt-hour (MWh) generated from	For the period 2016-2017, the renewable obligation certificates are issued from 0.5	One renewable energy certificate is issued for each megawatt-hour (MWh) generated from eligible	One renewable energy certificate is issued for each megawatt-hour (MWh) from eligible renewable source	One renewable energy certificate is issued for each megawatt-hour (MWh) from	One clean energy certificate is issued for each megawatt-hour (MWh) generated from eligible

Features	Sweden and Norway	UK	Australia	India	California	Mexico
	eligible renewable sources (d) (e)	MWh/ROC to 10MWh/ROC (e)	renewable source (c)		eligible renewable source (e)	renewable sources (c)
Shelf life of CEC and sunset clause of CEC market	The electricity certificates have a shelf life of 1 year from the issuance date / The electricity certificates will not be issued further than 2035 (f)	The renewable obligation certificates have a shelf life of 1 year / The maximum period for the renewable obligation certificate market is not after 31 March 2037 (d)	The small-scale technology certificates have a shelf life of 15 and 10 years, depending on the energy generation system. The large-scale generation certificates have a shelf life until they are cancelled /Renewable energy certificates cannot be created after 01 January 2031	The shelf life for renewable energy certificates have a shelf life of 3 years / The sunset clause of the renewable energy certificate market has not been defined yet	The shelf life of the renewable energy certificates is 3 years / The sunset clause of the renewable energy certificate market has been defined until 2030	The clean energy certificates have a shelf life until they are cancelled /Undefined (b)
Penalty scheme	The quota obligation fee is calculated based on 1.5 times the preceding year certificate price 187.95 NOK or 192.71 SEK for 2018 ($24.59 USD)	In case of non-compliance of the renewable obligation, Ofgem set a buy-out price of £45.58 ($61.47 USD) per MWh for the period 2017-2018 (b)	A shortfall charge of $65 AUD ($51.12 USD) must be paid by the obligated entities who do not surrender or purchase enough Renewable Energy Certificates (b)	The penalty fee for a non-solar certificate shortfall is Rs 3,000 ($46 USD) and for a solar certificate shortfall is Rs 2,400 ($37 USD)	The penalty fee for RPS non-compliance is $50 USD per MWh, up to $25 USD millions per year per entity	Mexican penalty fee calculation goes from $27 USD to $189 USD, depending on the non-fulfilment severity (e)

4.6.2 Summary of best practices, neutrals and failures

Table 4. 7: Summary table of best practices, neutrals and failures

(white), ✓	Best Practices	**S&N**	Sweden and Norway
(grey)	Neutrals	**UK**	United Kingdom
(black), ✗	Failures	**AUS**	Australia
		IND	India
		CAL	California
		MEX	Mexico

Processes/ Procedures	Goals	People/ Institutions	Infrastructure	Technology	Culture
Determination of CEC price ✗AUS (d) ✗IND (d)	Clean energy target ✓S&N (a) ✗AUS (e) ✗IND (c) ✓CAL (b) ✓MEX (a)	CEC Trading ✗IND (b)	Monitoring system or platform of CEC market ✓CAL (c)	Denomination of CEC ✗✗S&N (d) (e) ✗UK (e) ✗AUS (c) ✗CAL (e) ✗MEX (c)	Level of Experience ✓S&N (b) ✗CAL (d)
Shelf life of CEC and sunset clause of CEC market ✗S&N (f) ✗UK (d) ✓MEX (b)	Renewable Purchase Obligation (RPO) target ✓UK (c) ✗IND (e)	CEC Market Regulatory Authority		Classification of CEC ✗S&N (c) ✓UK (a) ✓AUS (a) ✓IND (a) ✓CAL (a) ✗MEX (d)	
Penalty scheme ✓AUS (b) ✓UK (b) ✗MEX (e)					

In accordance with the level of experience at the implementation stage of a clean energy certificate market, the creation of the Swedish and Norwegian joint market has developed and enhanced the performance in the certificates trading operations. Also, a greater strength to fulfil the compliance of the renewable energy targets. Evidently, the lack of a joint certificate market in California shows a weakness in the electricity industry infrastructure and the absence of collaborative programmes with neighbouring markets.

It is worth noting that the definition and the frequent amendment in the law to rise the long-term clean energy targets by the government of California have been favourable to increase the installed capacity of renewable technologies and provide certainty to investors for deploying large-scale renewable projects.

A constant evaluation of the clean energy certificate market by the regulatory authorities of the United Kingdom is essential for the market functioning alongside the goals of the stakeholders. As we have seen, the annual publication of the renewable purchase obligation in the United Kingdom is translated as a constant supervision and attention by the Office of Gas and Electricity Markets (Ofgem). Certainly, this action helps to update and make corrections to the clean energy certificate market on time and prevent future unforeseen events. There is also, however, a further point to be considered, the high efficiency in the Californian renewable energy certificate market has been based on its monitoring system or online platform named Western Renewable Energy Generation Information System (WREGIS), owing to this is the interaction mean between the regulatory authority and the obligated entities.

Nevertheless, the volatility of the certificate prices remains a growing problem, due to the lack of renewable purchase obligation compliance. For instance, the renewable energy generated in Australia was not sufficient, causing a record high in the certificate price. As a consequence, the Clean Energy Regulator could not properly avoid it, despite of the measures implemented, such as setting a reference certificate price. These efforts were not successful to maintain a stabilisation in the certificate price. Similarly, in the Indian market, the instability in the certificate price was caused by the different renewable purchase obligations defined by each state, which originated significant differences in the quantity of generated energy in each state.

Evidently, the implementation of a programme or a technology-banding scheme to support specific renewable technologies was the best practice and the most popular practice amongst analysed countries. In the United Kingdom, it has increased the amount of electricity generated from specific sources, because each renewable technology source has an especial treatment to boost its wider exploitation and take advantage of the availability of this natural resource. In the same way, the Clean Energy Regulator of Australia considered this measure to incentive both small-scale and large-scale renewable projects, due to the certainty offered to investors by the government of Australia. In addition, the programmes such as the Jawaharlal Nehru National Solar Mission or National Solar Mission in India, and the California Solar Initiative (CSI) in California, triggered the deployment of solar PV technologies. This implied to meet the clean energy targets established by the Central Electricity Regulatory Commission (CERC) (India) and the California Energy Commission (CEC) (California), respectively. However, it is important to emphasise that these actions can be strengthened with other factors, such as the term and a constant supervision of the clean energy certificate market behaviour, to make corrections if necessary.

The announcements of the closure of the clean energy certificate market made by the governments of Sweden and Norway by 2020 and the United Kingdom by 2016 and 2017, have halted the deployment of the renewable energy projects. In this sense, it was motivated due to the uncertainty of the Swedish-Norwegian market and the short deadlines to add new renewable generation capacity in the United Kingdom. Although other financing instruments granted by the governments exist for adding new generation capacity to the renewable energy share, such as the Guarantees of origin in Sweden and the Contracts for Difference (CfD) in the United Kingdom, the clean energy certificate markets have been affected owing to these closure decisions.

Finally, the design of the penalty schemes in the United Kingdom and Australia are simple and easy, because both penalty schemes established one single shortfall charge for the obligated entities to meet the renewable energy targets. As a consequence, these certificate markets reached high rates of compliance. This results in the ease of use in the certificates surrender process by the obligated entities in case of a shortfall in the renewable purchase obligation.

5 Recommendations for Mexico

In this chapter are underlined the contribution of the research project, identifying the best practices based on the experience and lessons learnt from the evaluated countries, emphasising the strengths and weaknesses of the Mexican market.

Firstly, the design features of the Mexican clean energy certificate market are analysed in order to identify the best practices and failures of the Mexican market through the socio-technical system approach. Afterwards, an assessment is made to define the best fitting findings for the Mexican market, paying particular attention to how the socio-technical approach has been applied. At the end of the chapter, the challenges that the Mexican market will face are defined according to the features of the clean energy certificate market design.

5.1 Market analysis

The Mexican renewable energy targets of 35% by 2024 and 50% by 2050 (SENER 2017a) are ambitious for a country, who its economy and energy generation share have been mainly depended on the fossil fuels over the last decades, particularly based on the oil and gas. It is worth noting that the Mexican government made an essential commitment to the definition of these renewable energy targets in the Energy Reform as discussed in Section 1.3.

It is important to note, however, that the Mexican renewable purchase obligation of 5.0% in 2018 (SENER 2015b) established by the Ministry of Energy, is relatively low in comparison to the evaluated countries according to the assessment explained in the previous chapter. This implies a conservative decision by the regulatory authority of the market, representing a strategic planning owing to the fact that the renewable purchase obligation was defined four years before its launch in 2018 (SEGOB 2014).

The Certificate Management and Clean Energy Compliance System (S-CEL) is the platform in charge of supervising the trading operations of the Mexican clean energy certificate market (CRE 2016a). This monitoring system is operated by the Energy Regulatory Commission (CRE) (SEGOB 2014) and its functioning is within the similar conditions of the monitoring systems of the evaluated countries. In the same way, the determination of the clean energy certificate price is defined in the spot market (SENER 2015a) by supply and demand, equally to the previously assessed markets.

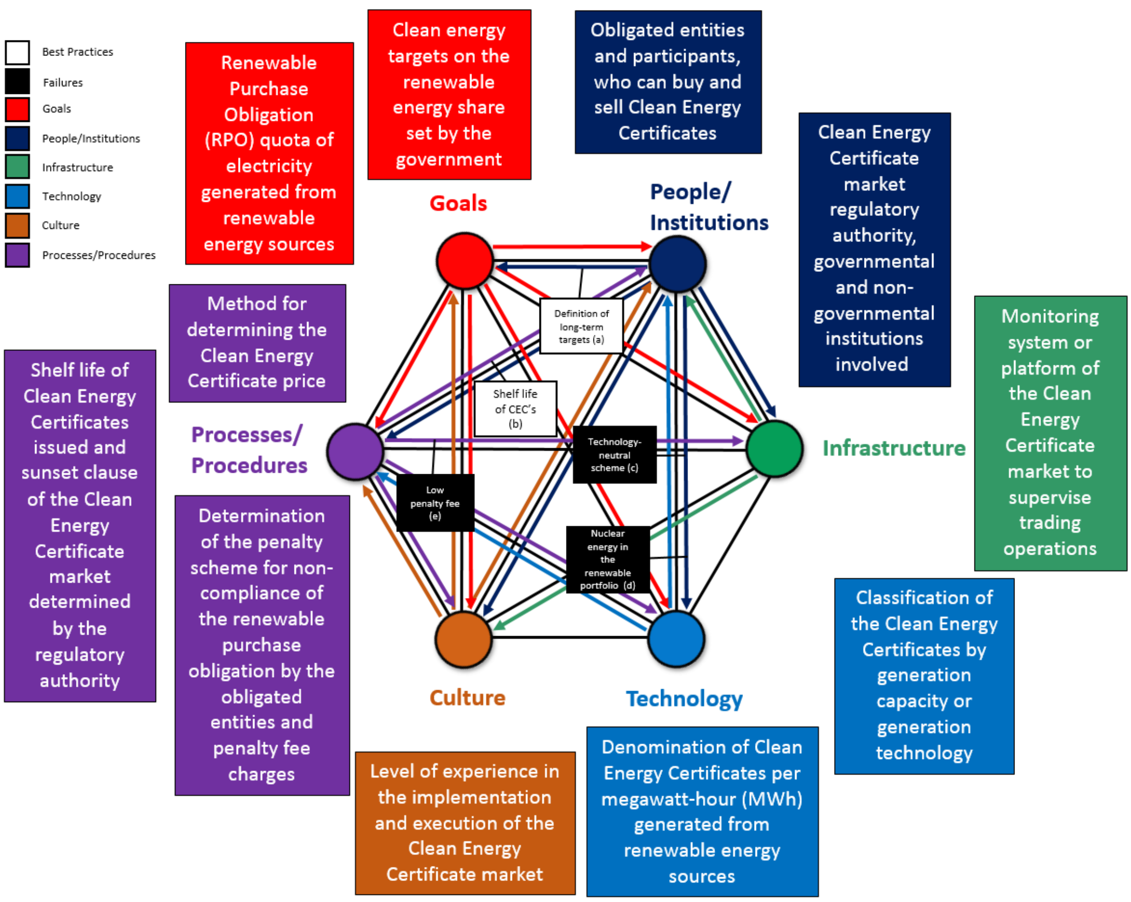
The Mexican market works under a technology-neutral scheme, but there is a particular feature that the evaluated countries do not have and is that the Mexican regulatory framework considers the nuclear energy as a renewable energy eligible for receiving certificates. Whereas, the other renewable energies eligible considered by the assessed markets and the Mexican market are solar energy, hydropower, wind energy, bioenergy, wave power and geothermal energy (SEGOB 2014).

Similarly to all the evaluated countries except for the United Kingdom, the Mexican clean energy certificates are issued per each megawatt-hour (MWh) generated from an eligible renewable energy source. The shelf life of the Mexican certificates (SENER 2014) and the large-scale generation certificates of Australia (Clean Energy Regulator 2017d) are the only ones, who have a shelf of life until they are cancelled.

Finally, the Mexican penalty scheme has 24 options for calculating a penalty fee that goes from $27 USD to $189 USD (CRE 2016b), starting with a very low penalty. This implies that the obligated entities might prefer to pay a penalty fee instead of fulfilling with clean energy certificates their renewable purchase obligation due to the low amount of the penalty fee.

5.2 Analysis from the socio-technical perspective

Figure 5. 1: Analysis from the socio-technical perspective of the Mexican CEC market



5.3 Best practices

5.3.1 Definition of long-term targets (a)[27]

In the Energy Transition Law are enacted the renewable energy targets as minimum rates in the electricity generation share from renewable sources (People/Institutions). These renewable energy targets were set at 28.3%, 35% and 50% for the years 2020 (Goals) (SENER 2017b), 2024 and 2050 (SENER 2017a), respectively. This long-term targets definition provides certainty to investors, particularly for the development of large-scale projects, motivating a widespread use of clean technologies (principles 1, 6).

5.3.2 Shelf life of CEC's (b)[28]

The Mexican clean energy certificates have a shelf life until they are surrendered (Processes/Procedures) by the obligated entities for fulfilling with their renewable purchase obligation (People/Institutions) (principles 4, 10, 11, 13) (SENER 2014). Amongst the evaluated countries, particularly, this design feature in the Mexican market is the same as the shelf life of the Australian large-scale generation certificates (Clean Energy Regulator 2017d).

Hence, assuming the experience obtained in the clean energy certificate market of Australia that showed a 99.4% of compliance in the surrendering process of large-scale generation certificates by liable entities in the 2015 period (Clean Energy Regulator 2016a). Thus, this design feature in the Mexican clean energy certificate market can be translated in a high rate of renewable purchase obligation compliance in the surrendering process by liable entities.

5.4 Failures

5.4.1 Technology-neutral scheme (c)[29]

The implementation of a technology-neutral scheme under the context of the Mexican clean energy certificate market (People/Institutions), where exists significant differences amongst the renewable energy resources available in Mexico (Technology) (principles 3, 16) (Table 1.1). For instance, the most abundant resources are the solar and wind

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[27] (a) This best practice can be found in Figure 5. 1 and in Table 4. 6 for analytical and comparative support, respectively.
[28] (b) This best practice can be found in Figure 5. 1 and in Table 4. 6 for analytical and comparative support, respectively.
[29] (c) This failure can be found in Figure 5. 1 and in Table 4. 6 for analytical and comparative support, respectively.

energy in comparison to other renewable energy resources. These significant differences hinder the competitiveness between the most and least abundant renewable resources in the electricity generation share in terms of having an equilibrium in the issuing of clean energy certificates.

5.4.2 Nuclear energy in the renewable portfolio (d)[30]

Certainly, the Mexican government has included nuclear energy in the renewable portfolio in its regulatory framework (People/Institutions). Namely, nuclear energy is considered as an eligible renewable energy source for issuing clean energy certificates in the electricity generation (Technology) (principles 6, 7, 10, 19) (SEGOB 2014). None of the evaluated countries considers the nuclear energy within the renewable energy portfolio as an eligible renewable source for receiving certificates in the electricity generation.

It is worth noting that the International Renewable Energy Agency (IRENA) does not include in its statutes the nuclear energy as a renewable energy. The renewable energies considered by the International Renewable Energy Agency are bioenergy, geothermal energy, hydropower, ocean energy (tidal, wave and ocean thermal), solar energy and wind energy (IRENA 2009).

This situation can create discrepancies between the international renewable commitments and the national renewable targets, regarding the quantification of renewable energy generated in Mexico.

5.4.3 Low penalty fee (e)[31]

The penalty scheme in the Mexican clean energy certificate market has established complacent penalty fees for the obligated entities (Processes/Procedures), through the application of a matrix for calculating the penalty fee (Infrastructure) to be paid by obligated entities (principles 11, 13).

This penalty fee is complacent due to the fact that the price of the Mexican certificate has been established in $24.30 USD for 2018 (SENER 2015a) and the penalty fees calculations start from $27 USD (CRE 2016b). This might imply that the obligated entities consider paying a penalty fee instead of surrender clean energy certificates. In addition, this penalty scheme may be complex, owing to the 24 options in the matrix for

[30] (d) This failure can be found in Figure 5. 1 and in Table 4. 6 for analytical and comparative support, respectively.
[31] (e) This failure can be found in Figure 5. 1 and in Table 4. 6 for analytical and comparative support, respectively.

determining the amount of the penalty fee to be paid by the obligated entities (Table 1.3).

5.5 Best international practices for Mexico

Once made the evaluation of the clean energy certificate market of Mexico in this chapter and the evaluation of the selected countries with high penetration of renewable energies through the implementation of clean energy certificate markets in the previous chapter.

This research project contributes with the findings of the best international practices as result of the evaluations made with the socio-technical system approach. The recommendations for the Mexican clean energy certificate market are given below.

5.5.1 Technology-banding scheme

The Mexican policymakers designed a clean energy certificate market under a technology-neutral scheme. Thus, based on the performance shown in the evaluation of the countries, the United Kingdom market has surpassed the performance amongst others.

As discussed in Section 4.2.3.1, it is important to note, however, that the clean energy certificate market of the United Kingdom was launched under a technology-neutral scheme in 2002. For 2009, the policymakers of the United Kingdom amended the regulatory framework to a technology-banding scheme. Resulting from this in an electricity generation from solar PV of 20 GWh in 2009 (IEA 2017l) to 7,561 GWh in 2015 (IEA 2017m).

As outlined above, the amendment from technology-neutral to technology-banding scheme has to be seriously considered by the Mexican policymakers, owing to the resources available in Mexico for renewable energies are predominantly by solar and wind energy (Table 1.4).

5.5.2 Penalty scheme simplicity

As Section 4.3.3.2, in the Australian market experience has been seen high rates of renewable purchase obligation compliance in the certificates surrendering process by obligated entities. In 2015, the small-scale technology certificates had a 99.9% of obligation compliance, whereas the large-scale generation certificates had a 99.4% of obligation compliance (Clean Energy Regulator 2016a). The Australian penalty scheme is characterised by having only one penalty fee of $51 USD in case of a non-compliance in the renewable purchase obligation (Clean Energy Regulator 2017f).

According to the analysis of the Mexican clean energy certificate market previously made in the Section 5.4.3. The penalty scheme presents weaknesses that may affect the rate of renewable purchase obligation fulfilment by the liable entities. On the one hand, the Mexican clean energy certificate price for 2018 is set at $24.30 USD (SENER 2015a) and the starting penalty fee is set at $27 USD (CRE 2016b). This low penalty fee may incentive the obligated entities to prefer paying the penalty fee instead of surrendering clean energy certificates. On the other hand, the penalty fee amount is determined through the application of a matrix with 24 different options for calculating the amount to be paid by the obligated entities.

Evidently, the findings of this analysis suggest the amendment of the Mexican penalty scheme. It consists in amending from a complex penalty scheme to a simple penalty scheme, including only one penalty fee in order to fulfil the renewable purchase obligation with high rates of compliance.

5.5.3 Solar Initiative

Drawing on the findings in Sections 4.4.3.1 and 4.5.3.1, the Indian and Californian governments established the National Solar Mission and California Solar Initiative (CSI), respectively. These solar initiatives have fostered the deployment of solar PV in both countries. In 2016, the solar PV installed capacity in India was 5 GW, becoming the fourth-largest worldwide in installed capacity added (India 2017). In the same way, the United States added 14.8 GW of solar PV installed capacity, becoming the second-largest worldwide in installed capacity added in 2016. This implies that the State of California added 5.1 GW, becoming the largest capacity added per State in the United States (REN21 2017).

There is, therefore, a definite need in the Mexican clean energy certificate market for the creation of a solar initiative or programme by the government of Mexico. A renewable policy priority should therefore be to plan for the long-term care of the deployment of the solar energy, supported by the solar potential available in Mexico (Table 1.4).

5.6 Challenges for the Mexican CEC market

From 2018, the Mexican clean energy certificate market will contribute to meet the renewable energy targets established in the Energy Reform enacted in 2013. The main challenge of the clean energy certificate market in Mexico is to achieve a wide deployment of renewable energies in the electricity generation share. In particular, the deployment of solar and wind energy, which are the most abundant renewable energies available in Mexico. This includes the enhancement in efficiency of the electricity grid in the country for avoiding significant energy losses.

The Mexican regulatory authorities have to supervise closely the market performance. In addition, after the first years of the clean energy certificate market implementation, a constant evaluation has to be considered by the Mexican policymakers in order to make the proper amendments on time to the design features if necessary.

Mexico has done significant efforts in the growth of renewable installed capacity throughout the country since the Energy Reform was enacted in 2013. There is a serious commitment by the Mexican government for boosting the use of clean technologies in the energy generation and the reduction of pollutant emissions for tackling the climate change. Certainly, the clean energy certificate market will accelerate the pace to reach the renewable energy target of 35% by 2024 (SENER 2017a).

6 Conclusions and future work

In the previous chapter was outlined the contributions this research project has made to the clean energy certificate market in Mexico. In this final chapter are addressed the aim and objectives of the research project, drawing on the insights acquired from the previous chapters and is highlighted the meaning of the research project for the Mexican clean energy certificate market. Finally, these insights are presented at the end of this chapter informing a number of suggestions for future work.

6.1 Addressing the research aim and objectives

Returning to the aim and objectives posed at the beginning of this research project and based on the findings as result of the evaluation of the countries, where has been implemented a clean energy certificate market. Indeed, the socio-technical system approach was applied as an analytical method presented in Chapter 4. It is now possible to address the aim and objectives set out in Chapter 1.

This research project set out an aim in Section 1.5.1. This is:

Evaluate the international best practices of the current clean energy certificate markets, identify the mechanisms to boost the clean energy certificate market of Mexico and provide practical guidance to deploy the use of renewable energy through the clean energy certificate market in Mexico.

One of the more significant contributions to emerge from this research project is the gathering of the design features of the countries under evaluation and the analysis made through the socio-technical system approach as outlined in Chapter 4.

In recent studies, the socio-technical system approach has been used in many investigational studies to present a detailed analysis. Although a variety of analytical methods could have been adopted, this study used the socio-technical system approach for a detailed analysis in order to gain insights into the clean energy certificate markets of the countries under evaluation using the socio-technical system approach as the analytical method in this research project.

This decision was made because of the detailed analysis that could be provided by the method to ensure a fair comparison of the clean energy certificate markets. Because the data was gathered from multiple sources it was important to use the same process to ensure the same criteria was applied for all of the countries being evaluated.

It was considered that the socio-technical system approach would usefully supplement and extend the analysis of the markets due to its benefit of mapping the components involved in the socio-technical framework.

The socio-technical framework captured and made clear the interdependencies and gaps amongst the components of the clean energy certificate markets. This analytical framework helped clarify and identify the best practices, neutrals and failures in the performance of the assessed countries.

This research project has shown that every country has to face different issues in order to succeed in the implementation of their clean energy certificate market. Although all the markets were designed with the same structure, the importance lies in the variation of the specific design features according to their own conditions as a country.

Governments have made strong efforts to support and incentive a widespread use of renewable technologies for electricity generation. However, policymakers should be aware of the well-design of the features when a clean energy certificate market is implemented in order to boost the renewable technologies.

The purpose of the current research project was to determine the best practices obtained from the evaluated countries in order to apply them to the Mexican clean energy certificate market to be launched in 2018 and enhancing its performance as discussed in detail in Section 5.5.

The aim established in this research project is complemented by four objectives set out in Section 1.5.2, which are:

- *Analyse the best practices and experience gained of leader countries with the implementation of a clean energy certificate market.*

The results of this research project (Chapter 4) show that the component in the socio-technical system approach, where the most of the best practices and failures of the evaluated countries were found, is coincidentally the component of *technology* in both cases. Firstly, the design feature with most of the best practices is the classification of the clean energy certificates by generation capacity or generation technology. This result reflected a prompt amendment of this design feature from the regulatory authorities due to poor performances of the markets during the first years of their implementation. On the contrary, most of the failures found in the evaluation of the countries is the design feature of the denomination of clean energy certificate per megawatt-hour (MWh) generated from renewable energy sources. These failures were based mainly on the lack of attention by the regulatory authorities.

This research project has gone some way towards enhancing our understanding of a proper intervention from the regulatory authorities can make the difference in the outstanding performance of a clean energy certificate market.

- *Make an assessment of the current clean energy certificate market design of Mexico.*

The design features assessment of the Mexican clean energy certificate market is detailed in the Section 5.1. It is important to note that the launch of the Mexican clean energy certificate market is in 2018, the regulatory authorities of Mexico have had the opportunity to analyse the performance of the global clean energy certificate markets in terms of defining an enhanced design. However, the results of this research project support the idea that through the analytical method of the socio-technical system approach, relevant findings can emerge for contributing to the performance of the Mexican clean energy certificate market.

- *Identify the gaps in the Mexican clean energy certificate market design.*

A number of gaps need to be noted in the clean energy certificate market of Mexico are highlighted in Section 5.4. These gaps can affect the performance of the Mexican market, but as explained above in this chapter, the regulatory authorities must be especially focused on these gaps. Indeed, it will be fundamental to consider analyse the behaviour of these design features once launched the clean energy certificate market of Mexico.

- *Aim to provide technical guidance for aid the deployment of renewable energies in Mexico through the clean energy certificate market.*

Therefore, the recommendations for the clean energy certificate market of Mexico are presented in Section 5.5. The relevance of these recommendations is clearly supported by the findings of this research project. The results of this research project support the idea that the recommendations proposed are intrinsically related to the component of *technology* from the socio-technical system perspective. Certainly, the evidence from this research project suggests that the regulatory authorities of the Mexican clean energy certificate market have to evaluate the design features under the socio-technical component of *technology.* Likewise, the results of the evaluation of the leader countries with high penetration of renewable technologies, show the component of *technology* as the component where are gathered most of the best practices and failures. Indeed, the Mexican clean energy certificate market presents most of its weaknesses and opportunities based on these recommendations for enhancing its performance, in the same socio-technical system component.

6.2 Future work

Further research should be done to evaluate the Mexican market performance once launched and make an analysis with real data collected from the Mexican market performance with the same analytical method used in this research project. It would be interesting to compare the results of these analyses of the market of Mexico before and after its implementation with the same analytical method. This is essential for deeper and more realistic evaluation after the first years of the clean energy certificate market implementation.

In addition, it would be interesting to assess the effects of the clean energy certificate market through a stochastic model with dynamic programming. Further work is required to propose forecasts of the Mexican clean energy certificate market through a variation in the current design features and afterwards evaluate the results obtained from those forecasts. For instance, a forecast of the price of the clean energy certificates can be made in order to know the existence of price fluctuations. Then, these results can be applied to improve the performance of the Mexican clean energy certificate market.

Finally, further research needs to examine more closely the links through interviews between the regulatory authorities and the reasons of why they structure the clean energy certificate markets in that particular way. Thus, the investigation should therefore concentrate on a deeper understanding for determining the involved factors in the definition of the design features. Afterwards, generate an abundant room for further progress in determining more accurate and enhance results.

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