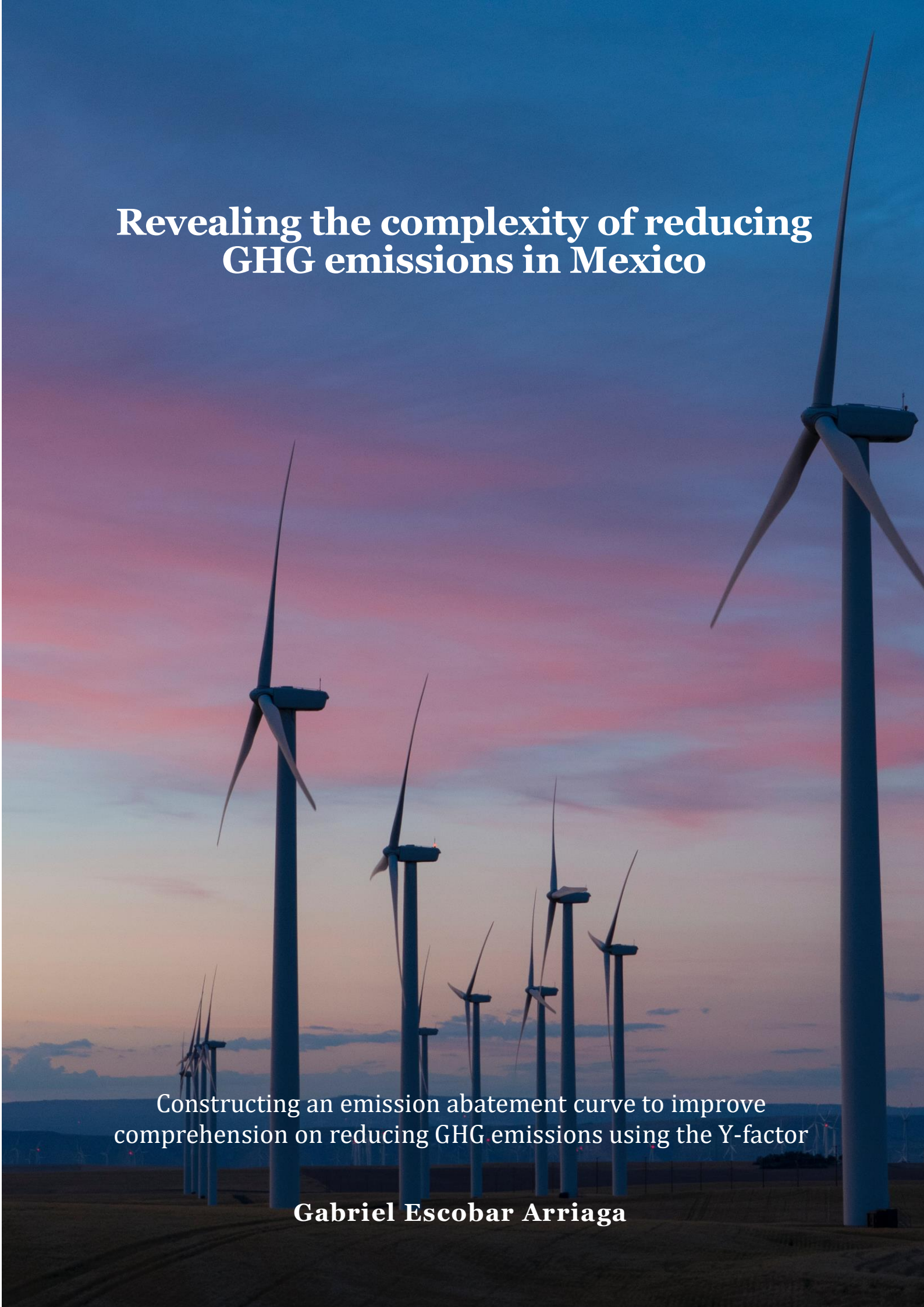

Revealing the complexity of reducing GHG emissions in Mexico

Constructing an emission abatement curve to improve comprehension on reducing GHG emissions using the Y-factor

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Revealing the complexity of reducing GHG emissions in Mexico

Master thesis submitted to Delft University of Technology

in partial fulfilment of the requirements for the degree of

MASTER OF SCIENCE

in Engineering & Policy Analysis

Faculty of Technology, Policy and Management

by

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To be defended in public on January 15th, 2020

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Acknowledgments

This thesis report concludes my journey on studying my master's degree at TU Delft. I would first like to acknowledge the full staff of the Engineering & Policy Analysis program that share their knowledge and added perspective on how to approach problems systematically, and also all the skills that were learned during their courses. I would also like to thank my thesis committee; Emile Chappin for his patience, guidance, and timely comments that helped me not only to finish my research but also valuable lessons on how to work, Els van Daalen was always open to questions regarding my process and also was curious about my personal well-being. I am thankful of how both mentored me, and I am glad that they could share their time with me. I would also like to thank the friends I made along the way and how I tried to absorb the best of each one of them.

Thank my family because without their continuous support this degree would not have been possible. My mom who continuously gave me encouraging words to succeed and to be better, my dad who always sees at the bigger picture and has always been there for me when I need anything, and my little sister who I am always trying to impress; thank you all. Lastly, my own family, Daniela who followed me in this journey to be in another country and have succeeded in what we have planned to do while also living day-to-day with the ups and downs on managing a master's degree, missing our family, raising our son and adapting to a new culture, you have helped me more than you can imagine. Finally, my son, Emilio just to see him smile and be happy is reason enough to motivate me in pursuing anything for him.

Executive Summary

Reducing GHG emissions has become a widely publicized topic to halt future effects of global warming. In an effort to accelerate the energy transition a group of policy-maker from McKinsey developed a tool named marginal abatement cost curve (MACC) capable of illustrating the relationship between the cost-effectiveness of different abatement options and the total amount of GHG abated (Bockel et al, 2011). Even though the MACC has become popular for government reports and environmental analysis of abatement options through their abatement cost it lacks to analyze the options beyond the financial perspective.

In 2016, Chappin published the introduction of the Y-factor method with the aim of solving the why factors that were hampering the pursual of implementing the abatement options. The method relies on the use of grading each abatement option in a scale of 0 to 2 through 12 socio-technical factors that are divided into four categories: multi-actor complexities, physical embeddedness, behavior and the cost & financing. This new method is a more robust approach than the MACC and it helps in providing new insights across different categories. The Y-factor is a relatively new method that has been furtherly assessed by Arensman (2018), Cheung (2018), and Soana (2018). This master thesis follows in the method of the Y-factor and goes a step beyond in proving its reliability when applied to a case-study, in this case applying the Y-factor for Mexico. The main research question is *What emission abatement curve can capture the complexity of reducing GHG emissions in Mexico?*

For the construction of the emission abatement curve this research focuses on 20 abatement options that are relevant for the country. These options were selected through a process to provide diversity in the sector and reflect the reality of the biggest GHG emissions contributors of the country (energy creation, transport sector). Through a preliminary scoring based on literature review including government reports, scientific and news articles a preliminary Y-curve was constructed. The validation of the emission abatement curve was provided by contacting different experts in the country. This validation relied on interviews made to provide insights of the current situation of Mexico further understand what is hampering the implementation of the abatement options. To remove subjectivity for the validation each of the abatement option was graded by 2 or 3 experts' interviews reducing personal bias and increasing result accuracy.

The validated Y-curve results had interesting insights when comparing to the initial MACC developed by the US government for the low emission development program in Mexico and presented by Rebolledo et al (2016). The energy sector had the highest scoring abatement options on average which included renewable options such as Geothermal, Wind-Energy, Small Hydroelectric while also including fossil-based options that have become a priority for the new government administration Coal CCS for new plants. From all the options the highest ranked option according to the Y-score was the Coal CCS retrofit with a score of 22 out of 24. This means that this is the least convenient

option to be pursued according to the grading across the four categories. It was also interesting to note how the transport sector with options such as modal shift freight transport, transport policy changes, hybrid and electric vehicles, among others conform a highly diverse group each with different goals and widely different factors that obstruct its pursual. A key area is how the transport sector is dependent on a lot of different actors for any structural change or policy implementation meaning that these options are some of the most difficult to follow specially in the cities. Results of the Forestry & Agriculture cluster can be misleading if only the McKinsey data is available given the peculiarities of how the plot areas of land are owned in the country making it a unique situation that is hard to conceive in different countries. A general link between Mexico's current affairs and the abatement options selected are explained to provide valuable information on the country and possible pitfalls when dealing with similarities in other countries.

At the end of the report a recapitulation of the process and the main steps of the thesis are provided, as well as, concluding remarks for each chapter are mentioned to highlight the most important aspects of them. Valuable suggestions given by the interviewees on how to improve the Y-factor method have been highlighted, as well as the limitations of the study and how it can be improved. The societal and academic relevance of the project, as well as the limitations of the study are addressed and given an opinion of the added value of using the Y-factor for future research purposes is given. Concluding, the Y-factor approach adds value to decision makers and serves its main purpose of understanding the factors that hamper the abatement option implementation while also helps in unravel the complexity associated with such abatement options to a better overall understanding.

Table of Contents

Acknowledgments 4
Executive Summary 5
Table of Contents 7
List of Figures 8
List of Tables 8
1. Introduction 11
1.1 Y-factor 12
1.2 Knowledge gap 14
1.3 Engineering & Policy Analysis Perspective 15
1.4 Methodology 16
1.4.1 Desk Research 16
1.4.2 Expert Interviews 17
1.5 Outline 18
2. Abatement options 21
2.1 Selection procedure of abatement options 21
2.2 Overview of abatement options selections 25
2.3 Chapter 2 Conclusions 34
3. Preliminary Y-curve 37
3.1 Scoring of Abatement Options 37
3.2 Preliminary Y-curve 48
3.3 Chapter 3 Conclusions 49
4. Validated Y-curve 53
4.1 Interview procedure 53
4.2 Interviewed experts 53
4.3 Interview Results 55
4.4 Validation Process 56
4.5 Validated Y-curve 64
4.6 Chapter 4 Conclusions 64
5. Results Analysis 69
5.1 Comparison preliminary Y-curve & validated Y-curve 69
5.2 Comparison between Ranking MAC and Ranking Y-curve 70
5.3 Y-factor meaning in Mexico's current affairs 71
5.4 Chapter 5 Conclusions 74
6. Conclusions & Recommendations 77
6.1 Thesis recapitulation 77
6.2 Recommendations to reduce GHG in Mexico 81
6.3 Limitations of the study & suggestions for the Y-factor 82
6.4 Reflection 83
7. References 87
Appendix A: Abatement options selections 96
Mexico MAC Curve 96
Abatement options shortlisted through Y-factor 97
Appendix B: Interview Template 98
Appendix C: Extended Interview Results 99

List of Figures

Figure 1: Outline diagram 18
Figure 2: Mexico's GHG Emissions by Category, 2010 (percent of totals) 22
Figure 3: GHG Abatement Cost Curve for Mexico, 2020 22
Figure 4: Cost & Financing chart 37
Figure 5: Multi-actor complexity chart 40
Figure 6: Physical Interdependences chart 43
Figure 7: Beahvior chart 45
Figure 8: Preliminary Y-score chart 48
Figure 9: Preliminary Y-score disaggregated by factors 49
Figure 10: Validated Y-score by factor 64

List of Tables

Table 1: Y-factor 13
Table 2: Abatement options for Mexico with definitions 24
Table 3: Experts & Affiliation 53
Table 4: Abatement options cross-referenced with experts 54
Table 5: Interview results 55
Table 6: Validated Y-score table 57

SECTION 1
Introduction

CONTENT

1. Introduction

1.1 Y-factor

1.2 Knowledge gap

1.3 Engineering & Policy Analysis Perspective

1.4 Methodology

    1.4.1 Desk Research

    1.4.2 Expert Interviews

1.5 Outline

01.

1. Introduction

According to an announcement stated by the International Energy Agency (2015), what has been done so far in terms of energy policy is not enough to accomplish the challenging mission of drastically reducing greenhouse gas (GHG) emissions levels in the atmosphere. Energy generation, heat production, and transportation are some of the highest contributing sectors to GHG emissions in the world (Reynolds, 2013; Diesendorf, 2018). This has led to the necessity to optimize current operations across different sectors or drastically change how energy is being generated. Government and enterprises require knowledge to reduce GHG emissions while also maintaining their economic targets for the emission abatement to be feasible.

An increasing sense of urgency has countries creating policies and measures capable of dealing with global warming. Nevertheless, even though measures are being implemented, only a handful of countries, such as India, Costa Rica, Morocco, among a few others, are currently on track to meet their 2030 targets while countries in Europe and America are showing moderate progress but might not be able to meet the targets proposed in international agreements (Climate Action Tracker, 2019). A potential shift in how the world is approaching this issue needs to be performed to achieve its goal of reducing these emissions. To successfully achieve this change, governments, and policymakers need to understand the factors that are hampering the progress of mitigating these emissions and successfully use that knowledge to create policies capable of mitigating GHG emissions.

In accordance with international agreements, Mexico has joined the premise of reducing its GHG emissions. Mexico has been willing to participate and contribute to lowering its current GHG emissions, the country has adopted an institutional framework for climate change action. A milestone was the enactment of the 2012 General Law on Climate Change, which distributed responsibilities among federal, state and municipality's government to tackle climate change mitigation by setting goals and adaptation challenges (Rebolledo et al, 2016). The 2015 Intended Nationally Determined Contribution expanded the General Law's goals by establishing that Mexico would aim to reduce its GHG and Short-Lived Climate Pollutant emission by 30% below business as usual by 2030, and 50% by 2050 (Mexican Government, 2014). Since the adoption of the first Special Climate Change Program in 2009, Mexican federal and subnational agencies have strengthened their capacity to develop climate change policies and programs, supported by scientific and technical analysis (Rebolledo et al, 2016). Nevertheless, after two successive federal administrations (2006-2012, 2012-2018) adopted climate change programs that integrate the main elements of Mexico's Low Emission Development Strategy developed by the International Aid agency of the US, including a process that delimits roles and responsibilities, an assessment of the current situation, as well as, business as usual scenarios with potential projections, and action prioritization (LEDS, 2018). A shift in attention on climate change has been surprising since a new administration started its regime in

2018. Furthermore, current scientists and policymakers have advocated to explain the lack of focus in mitigating GHG emissions (Domínguez, 2019). The development of an emission abatement curve is a viable path to reveal the complexity of reducing GHG emissions in Mexico and better prepare policymakers in their strategy to complete the country's emission reduction goal by 2030.

The Marginal Abatement Cost Curve (MACC) is a popular tool for ranking emissions abatement options. A MACC represents the relationship between the cost-effectiveness of different abatement options and the total amount of GHG abated (Bockel et al, 2011). By using this tool, the focus relies on the costs involved for reducing GHG emissions; this makes MACC one-dimensional while common criticism of the results is based on the acknowledgement that MACC fails to capture the whole complexity that require mitigating the emissions. A recently proposed method that aims to expand on this application is the Y-factor method, first introduced by Chappin in 2016. It is composed by 12 ranking criteria, commonly referred as factors, that aim to uncover the relevance of the social and technical barriers that hamper the implementation of emission abatement options. The Y-factor is determined by scoring an abatement option per factor (0, 1 or 2) and summing them. The result of the sum of the factors reveals why (Y) an abatement option is difficult to achieve (Chappin, 2016). This thesis will attempt to construct a validated emission abatement curve using the Y-factor method, as well as potential applications of the curve to help decision-makers in generating effective energy strategies for Mexico.

1.1 Y-factor

The Y-factor method aims to measure the relevance of 12 socio-technical factors in affecting the implementation of emission abatement options. The Y-factor uses four categories to cluster those factors; these are: costs and financing, multi-actor complexity, physical interdependences and behavior. Each of the factors will have a value which can be 0, 1, or 2, the number represents how difficult is to realize an abatement option in the any given factor (Chappin, 2016). At the end a sum of all the values is performed and the abatement options with the higher number will be the harder to implement. A table is provided to show the 12 factors, categories and what each value means.
The first attempt to construct an emission abatement curve was performed by Chappin in (2016) when he self-scored 50 of the abatement options that had the highest abatement potential provided in the McKinsey marginal abatement cost curve. Further refinement of the method was carried out by Cheung (2018) connecting the Y-factor with transition theory and Arensman (2018) who classified the Y-factor as a research method. Soana in 2018 constructed the first reliable emission abatement curve in a global scale using expert interviews to validate scoring and reduce subjectivity.

Category	Factor	Value 0	Value 1	Value 2	Definition
Costs and Financing	Investment cost required	Absent	Medium	Large	Degree to which the investment in an abatement measure is significant
	Expected pay-back time	< 5 years	5-12 years	> 12 years	Expected time required to earn back the investment for an abatement measure
	Difficulty in financing investment	Low	Medium	High	The degree to which it is difficult to finance the abatement or attract appropriate financial means
Multi-actor Complexity	Dependence on other actors	No	Little	Much	Degree of dependence on actions of other actors to successfully implement and execute the abatement measure
	Diversity of actors involved including conflicts	Low	Medium	Large	Degree of diversity of interests, values, roles, skills and expectations of the actors involved. Degree of public acceptance. When opposing interests from the (local) public to the implementation of the abatement option are (expected to be) present, a high score should be given'
	Division of roles and responsibilities unclear	Clear	Slightly	Unclear	The extent to which the roles and responsibilities for the realization of the abatement option are clear
Physical Interdependences	Physical Embeddedness	No	Medium	High	Degree to which the abatement measure requires physical changes to the environment it is placed in
	Disturbs regular operation	No	Slightly	Strongly	Degree (duration, intensity) to which status quo/regular operation is disrupted to successfully apply the abatement measure
	Technology uncertainty	Fully proven	Small	Large	Degree to which the technological performance of the abatement measure is uncertain
Behavior	Absence of knowledge of actor	High Knowledge	Low Knowledge	No Knowledge	Level of knowledge of the parties responsible for the abatement measure
	Frequency of opportunity	Often	Medium	Rarely	Number of opportunities for the responsible party to realize the abatement measure
	Require change in behavior	No	Slight	Severe	Degree to which the actors involved need to change their day to day behavior

Table 1: Y-factor

1.2 Knowledge gap

After being introduced by Chappin (2016), the Y-factor method has been further analyzed and put into practice by Arensman (2018), Cheung (2018), Soana (2018), and Swart (2019). They have made comprehensive progress in expanding the Y-factor method while also validating the abatement options, factors, and building the subsequent emission abatement curve. Nevertheless, the Y-factor has only been tested in one market, the Netherlands. To further enhance the capabilities of the Y-factor it needs to be expanded to a new region or country to continue its method validation.

The country selected is Mexico given its different geographical location, government structure (President and Secretaries), population (more than 120 million), and energy potential (solar energy) differences from the Netherlands. Characteristics such as an overreliance on using cars (no passenger trains, lack of sustainable public transport in cities), a dependency on oil extraction and refinery, and a new government administration that lacks focus on keeping environmental targets causing increasing GHG emissions due to new agenda makes Mexico a suitable candidate to be studied. The construction of a reliable emission abatement curve for Mexico using the Y-factor method is the knowledge gap that will be tackled in this report.

There are written climate mitigation reports about Mexico which mention the use of a marginal abatement cost curve (Veysey et al, 2016; Rebolledo 2016), even though these reports are well written from a financial standpoint when using the MAC curve their cost-oriented nature tends to overlook several factors that also play a role in the emission mitigation. The more robust approach that the Y-factor delivers where it includes not only the costs, but also the multi-actor complexity, their behavior and the physical interdependence better pictures the whole complexity of the situation.

Given the above information the research question is as follows:
What are the key complexities of reducing GHG emissions in Mexico?

Given the nature of the research question, several sub-questions were developed with the idea to be components of the main research question. They will help picture a clearer image of how the process will be done.

Sub-questions:

- *What are the relevant abatement options needed to reduce GHG emission in Mexico? CH2*
- *How can the Y-factor method identify the barriers that are hampering the implementation of the selected emission abatement options? CH3*
- *How can expert interviews improve the understanding of the barriers that hamper the emission abatement options through the Y-factor method? CH4*
- *What are the implications of the Y-factor scores? CH5*

1.3 Engineering & Policy Analysis Perspective

At the core of its content the Engineering and Policy Analysis program teaches how to understand, analyze, and solve complex problems that are present in today's world with a special focus in the popularly called "Grand Challenges". In this master thesis, the central topic is what hampers the implementation of emission abatement of greenhouse gas emissions in Mexico. During my time as a student, in my lectures I was always reminded to look at the different angles of a situation, look for the actors involved or search for societal issues. The use of the Y-factor that is been used for this research follows that pathway and aligns to the core of what the program teaches. A complex set of abatement options were meticulously studied to understand why the were not been implemented by analyzing beyond the financial constraints, and examining its multi-actor perspective, the physical embeddedness, and the potential behavior changes that each option. This makes the Y-factor method a robust approach and the results are central to provide insightful information for policy-makers in their quest to design effective measures and changing the current energy system in the country to one that can contribute to the reduction of the GHG emissions and the subsequent energy transition.

This project not only tested my academic knowledge but also my interpersonal skills. I had to design efficient interviews where I had to communicate in an effective manner and state the intent of the research in a way clear that was clear for the interviewee. Also, busy schedules and complications to have remote meetings meant that I had to maximize the limited time available that experts were giving me to validate the results that were obtained, as well as, condensing the most important information given by each of the experts into useful insights for readers. Both qualities also had strong support during the EPA project by giving us courses and workshops to improve our interpersonal skills and obtained the desired results.

1.4 Methodology

The following section aims to deliver on the methods that are used in this research.

1.4.1 Desk Research

1. The aim of the desk research is to understand which are the most important abatement options that influence the abatement curve. To do this, a literature research was conducted with a range of scientific papers (Chappin, 2016; Kelsicki, 2011) news articles (Reynolds, 2013; Diesendorf, 2018), and reports (Soana, 2018; Swart, 2019; Rebolledo, 2016) been studied.
   The selection of the abatement options will be made by following steps that help determine the most interesting option to pursue forward. The steps that were followed are the following.
   Step 1: Make a first table with the first draft of abatement options based on prior knowledge and other country reports.
   Step 2: Use the MACC to crosscheck the selections made and analyze if a change needs to be performed. The analysis of the curve will focus on both spectrums of the histogram where the marginal abatement cost [€/tCO_2e] is greater than 0 and when the marginal abatement cost is lower than 0.
   Step 3: Check similar abatement options to the ones selected and crosschecked their values. Select the most representative of the options per sector.
   After the selection of the abatement options each option have a detailed description of their emissions number, definition, costs, potential issues, and characteristics of Mexico.

2. Another objective of the desk research is performed in analyzing the relevance of the factors that obstruct the implementation of the emission abatement options. This relevance was based on a quantitative scoring (0-2). This research focused on government and scientific reports on Mexico (Rebolledo, 2016; CAT, 2019; SEMARNAT, 2014) that provided, when possible, quantitative data to back-up the scoring or have enough qualitative input to make the scoring of the factors of the given abatement option.

The main sources for the desk research were on scientific reports involving the Y-factor. literature involving emission abatement (global, and local), and government reports (local). The result of this method is to have a preliminary Y-curve. This Y-curve was entirely based on the literature available while the next step was the validation of the Y-curve by using the opinions and knowledge of experts on the field, this step is further explained in the section below.

1.4.2 Expert Interviews

The aim of the interviews is to have experts revising the abatement options that are deemed as important for the curve to be constructed. Every option has been checked by a group of experts, this led to have a comprehensive outlook of the options that are deemed as important for the construction of the curve. Furthermore, they checked if the assessment of those options is correct or if a scoring change must be made to better reflect the current situation. The experts are knowledgeable and actively involved in the energy sector of Mexico. These interviews were mainly carried out remotely given the resources available. The number of interviews was designed to have at least two persons validating the abatement option relevancy and the values given for each of the factors, 8 persons were interviewed. The way these persons were arranged is the following: have emissions experts' opinions that can read the full range of sector or most the of abatement options by each sector and validate or change the scoring given and have field experts that their area of expertise is regarding the sector of that each abatement sector. A table with the names of the interviewees is presented on chapter 4.

The interviews had a structured approach (varied from 30 min - 1 hour), the material used for the interviews can be found in the appendix. All of the interviews started with a general introduction with an emphasis on the goal of the interview (max 5 minutes), the next part is for the interviewee to select one of the abatement options and start checking the preliminary results gathered, the interviewer asked for more details when a different score from the one presented in the preliminary curve was obtained. As expected, sector experts had lengthy discussions on their abatement options of expertise (45 minutes depending on each interviewee time availability). The result of this method was used to validate the preliminary Y-curve made on the desk research and presented in chapter 3.

1.5 Outline

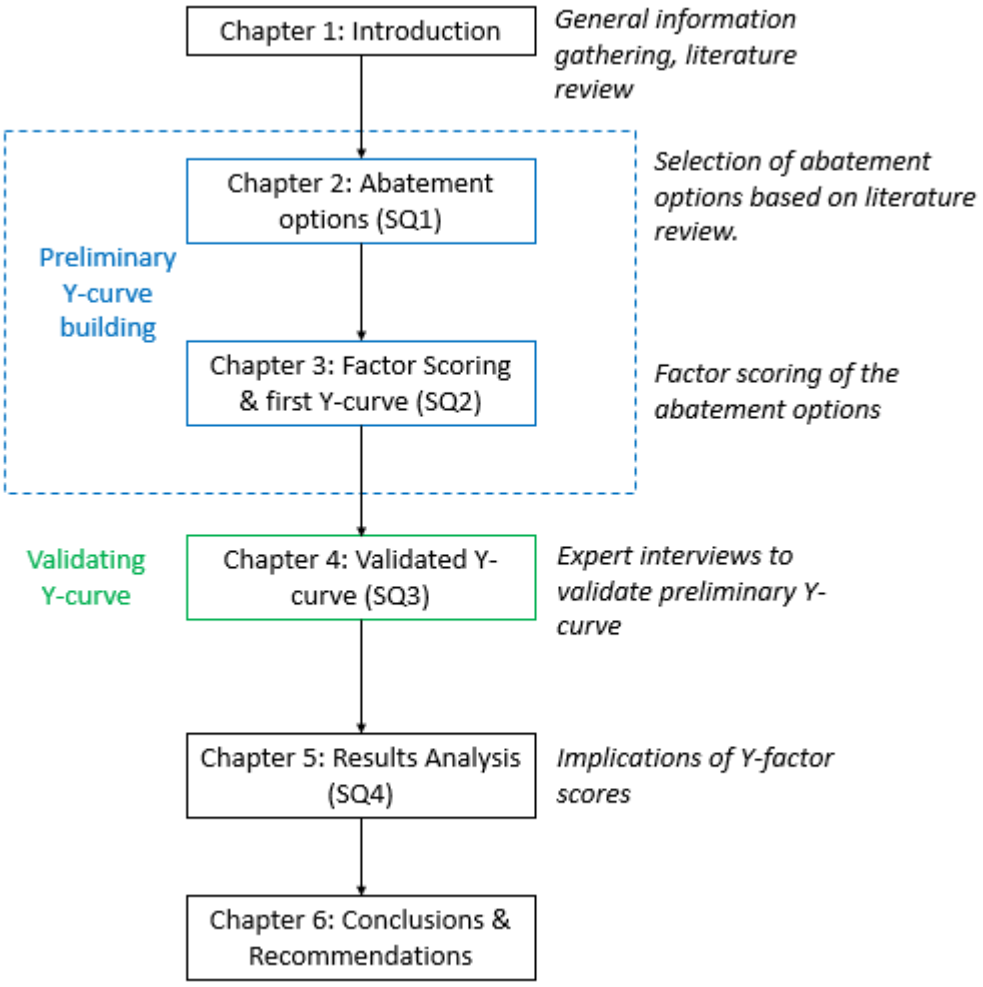


Figure 1: Outline diagram

Figure 1 showcases the outline process of the report. It is divided into 6 chapters were the research questions are answered and conclusions are been drawn.

SECTION 2
Abatement options

CONTENT

2. Abatement options

2.1 Selection procedure of abatement options

2.2 Overview of abatement options selections

2.3 Chapter 2 conclusions

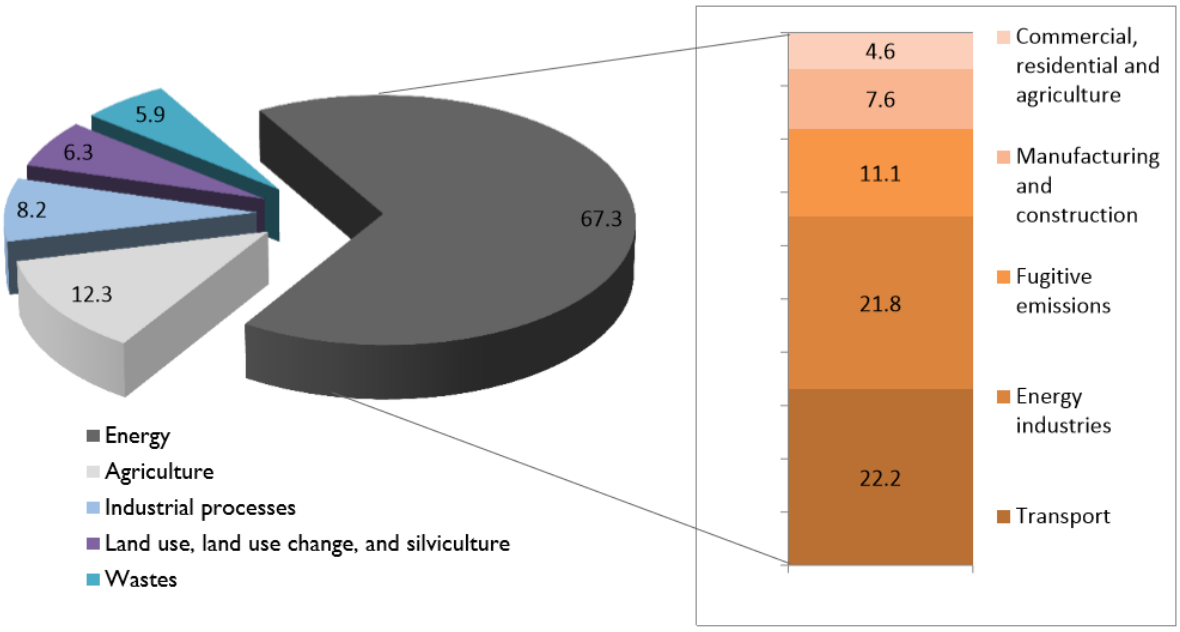
02.

2. Abatement options

This chapter revolves around the sub-question *What are the relevant abatement options needed to reduce GHG emission in Mexico?* It presents how the procedure for selecting abatement options was performed, as well as, a comprehensive outlook of the characteristics and attributes of every abatement option selected. The options that are going to be presented has been selected to represent GHG contributors across different sectors, given time constraints of the project a limited number of options was selected to fulfill to comply with time constraints.

2.1 Selection procedure of abatement options

Given the timeframe available for the development of this research a limited number of abatement options had to be selected. One of the key features in this project is the ability to select what are, arguably, some of the most impactful abatement options for Mexico considering literature review and current government agenda. A key resource to help with the selection is the use of the marginal abatement cost (MAC) curve tailored made for Mexico in 2013 by the USAID during the Low Emission Development Program. The main objective when selecting the abatement options is to form a group capable of representing the different sectors that contribute to the GHG emissions in the country (*Figure 2*).



Note: Fugitive emissions are GHGs that are intentionally or unintentionally emitted during the extraction or processing of fossil fuels, as well as during their delivery to their point of use.

Figure 2: Mexico's GHG Emissions by Category, 2010 (percent of totals) (Rebolledo, 2016)

Selection Criteria

As explained during the report the importance of using the method of the MAC curve developed by Mckinsey is a key reference for this research. The complete pool of abatement options consists of

2018 options that are included in the Mckinsey global cost curve. These options are the reflection of a global scale and in the case of this report the lens is on one country, Mexico; hence the main figure to be used is the GHG Abatement Cost Curve for Mexico (Figure 2) which consists of fewer options than the global curve. To further aid in the selection procedure the utilization of the abatement options use by Chappin (2016) in the research of the Y-factor are the main options that are considered (50 options) and ultimately reduced by Soana (2018) crosschecking with current trends in the Mexican market. The combination of these resources will help determine in a concrete manner the most impactful options to analyze and construct the subsequent abatement cost curve for the country using the Y-factor method.

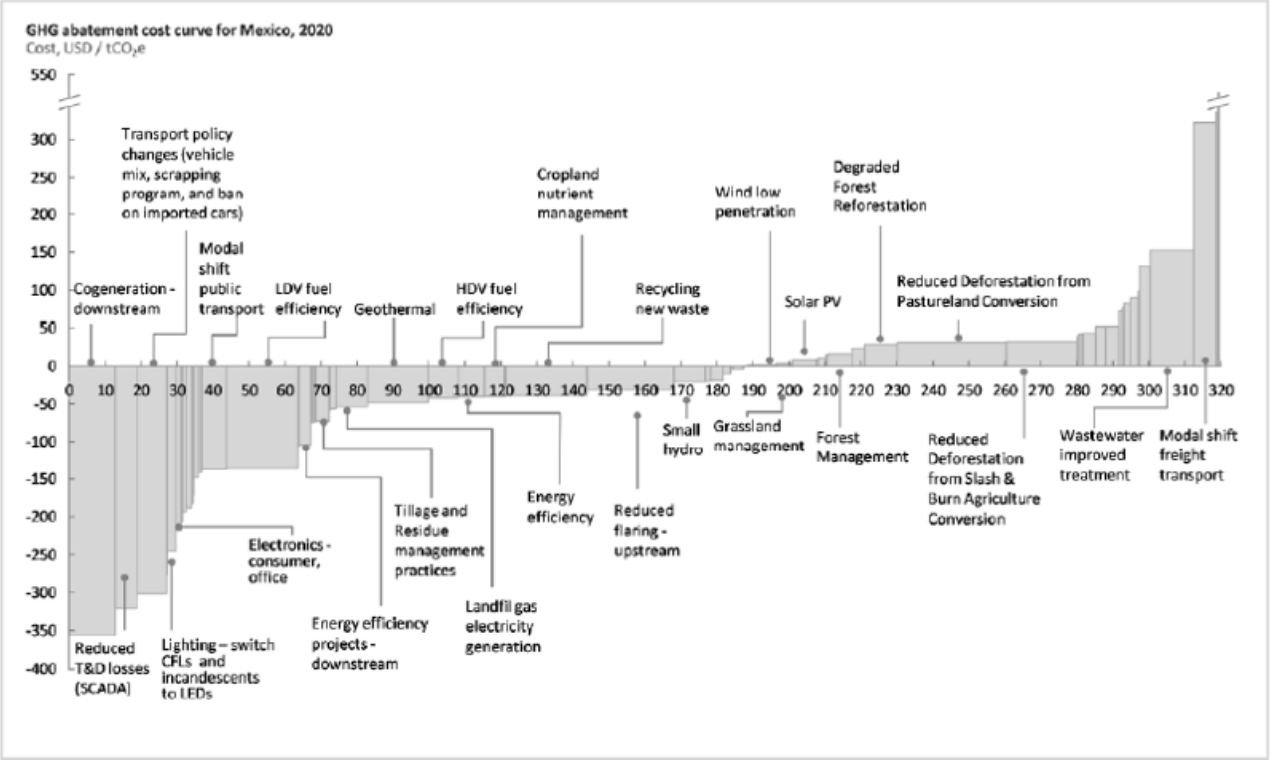


Figure 3: GHG Abatement Cost Curve for Mexico, 2020 (Rebolledo, 2016)

Considering the time available to produce this report the abatement options that are selected stands at 20 which is an amount deemed as enough for the construction of the subsequent abatement curve. The 20 abatement options are going to be selected through a multi-criteria selection process which emphasize on having diversity and enough representation of the most impactful sectors in the country.

Two main sources of diversity can be highlighted in the pool of options considered by Soana (2018):
a) Reflecting from the classification provided in the McKinsey's MAC curve, the abatement options considered belong the 9 different economic sectors: Building, CCS, Energy, Household Changes, Industrial Processes, Forestry & Agriculture, Fuels, Vehicles, and Waste.
b) McKinsey's MAC curve only ranks the abatement options in terms of their marginal abatement cost. A division of which options produced negative or positive cost is performed to aid with the

selection process. It must be remembered that this is a global curve and that the research focuses on Mexico, thus making additional abatement options from the shortlisted pool a possibility.

The selection process is constructed using both the abatement options by the research of Soana (2018), and the case-specific cost abatement curve of Mexico provided by Rebolledo (2016).

Step 1: Crosscheck which options are present in both literature resources.
This means that each option belonging to the McKinsey global curve reduction made by Soana (2018), and the Mexico MAC curve presented by Rebolledo (2016) needs to be checked for which abatement options appear on both charts.
Step 2: Marginal Abatement Cost in McKinsey's MAC global curve and the MAC curve for Mexico.
Divide the options selected in Step 1 in two sub-groups: one containing the abatement options with MAC lower than 0, and the other containing the abatement options with MAC greater 0, as ranked by the MACC.
Step 3: It is important to have multiple sector representation, so the selections need to be diverse to have a more robust picture of the GHG emissions of the country.
Select the most important abatement options from each of the two sub-groups:

a) Select representative abatement options considering sector diversity.
b) Select the options that fulfill current trends (renewable energies, transport sector abatement options).

Some limitations in the selection criteria is that the data used by Soana can be outdated as is a global score with no curve made by McKinsey for Mexico, and the other being that the Rebolledo curve has also outdated data and might not reflect current trends from the new administration (2018-2024) in the Mexican government. The abatement options presented in Rebolledo are preferred given that they were tailored-made at the time for the country. At the end, the abatement options selected are believed to fulfill diversity, as well as, current trends of abatement options globally and in Mexico. For easier recognition the options were clustered in 5 sectors rather than 9 given the limited number of abatement options and the discrepancy in GHG emissions for the Energy sector and Transport sector in the country. An expansion of the tables of Rebolledo (2016) with marginal abatement cost approximation, and the shortlist made by Soana (2018) is present in the Appendix A section.

The abatement option selections are as follows:

Sector	Abatement Option	Definition
Waste	Electricity from Landfill gas	Gas produced from large landfills that can be commissioned for electricity generation.
Waste	Waste composting & recycling	Sort solid waste for recycling purposes (organic, paper, glass, metal, hazardous, etc.). Waste composting is a bio-process with the compost ending as the result (can lead to further applications).
Transport	Air transport	operations-efficiency improvements, using alternative fuels
Transport	Modal Shift Freight Transport	Optimization of operations on how freight transport is delivered (earth, sea, air)
Transport	Transport Policy Changes	Optimization in transport use, restrictions of high emission transport, vehicle limitation use by regulation
Transport	Heavy duty vehicles fuel efficiency	target reductions in fuel consumption, carbon dioxide, or greenhouse gas emissions for HDV
Transport	Light duty vehicle fuel efficiency	target reductions in fuel consumption, carbon dioxide, or greenhouse gas emissions for LDV
Transport	Battery Electric Vehicles	electric vehicle that utilizes energy that is stored in rechargeable battery packs to work. Do not use internal combustion engines.
Transport	Hybrid Vehicles	A hybrid vehicle has two systems in parallel, one is the electrical drive system and the other is the internal combustion engine. The electrical system runs when certain conditions are being met providing relief to the ICE.
Household	Lighting switch residential	switching CFL and incandescent light bulbs to LEDs
Forestry & Agriculture	Agronomic practices	Practices to improve soil quality, optimize use of water, handling of crops, and soil treatment improvement that are incorporated in the farm management system.
Forestry & Agriculture	Reduced Deforestation	Reduction of forest and trees removal to be transformed to non-forest use (farms, urban areas).
Forestry & Agriculture	Grassland Management	Handling, and manipulation of the land's natural vegetation in order to achieve certain objectives like increased grazing intensity, increased productivity, without using fertilizers, improve irrigating system for grasslands, and potential introduction of new animal or vegetation species.
Energy	Nuclear Energy	Generating power from nuclear energy
Energy	Geothermal Energy	Large scale geothermal energy generation
Energy	Low-penetration wind	Wind energy harnesses the kinetic energy of moving air with a penetration of the energy mix lower than 10%.
Energy	Small Hydroelectric	Small scale hydro energy generation
Household	Home Solar Photovoltaics	conversion of light into electricity using semiconducting materials that exhibit the photovoltaic effect for home panels
Energy	Coal CCS retrofit	Capturing of CO2 in an existing coal plant
Energy	Coal CCS New-Built	Building a coal power plant with the inclusion of the CCS technology.

Table 2: Abatement options for Mexico with definitions

2.2 Overview of abatement options selections

This section aims to provide clarity on the definitions of the abatement options selected, their current characteristics in the world and the characteristics in the case study based on existing literature. The options selected are meant to provide diversity and representation of major sectors that contribute to the GHG emissions system. They have been arranged by sectors to facilitate understanding and clustering of the abatement options.

2.2.1 Energy

Nuclear Energy

Definition: Energy generation in nuclear power plants
Emissions: 90-140 gCO2e/kWh
Costs: There is not an exact formula for forecasting costs for a new nuclear plant, it involves a lot of variable costs depending on site of construction, country, land soil, etc. An example of one project in Georgia called Vogtle 3&4 had a total cost of 14 billion USD for a capacity of 2234 MW. Estimated LCOE costs between 0.075 USD / kWh and 0.081 USD / kWh for new nuclear plants (service in 2023).
Potential Issues: Side-effects of development of nuclear weapons, radioactive waste, market uncertainties
Mexico: New plant not currently planned, one operational 39-year plant in the country. Electricity generation of 3% of the country's total. Expected to revise new investments in the sector in 2030.

Sources: World Nuclear Association (2019), IPCC (2012), US EIA (2019), Solís (2018), Energía Nuclear (n.d.)

Small Hydroelectric

Definition: Small scale hydroelectric generation.
Characteristics: Water moving in a high to low direction using geographical elevations to harness energy and subsequently create electricity. These plants are usually built in rivers that vary in elevation and have on average a capacity between 20 and 50 MW
Emissions: hydroelectric do not emit GHG emissions, potential in decomposing metals over a longer period.
Costs: LCOE worldwide average ranges from USD 0.04 and 0.06/kWh in every part except Europe where the average is USD 0.11/kWh.

Potential Issues: requirement of continuous water movement, potentially isolated (lack of connections), high investment costs, relocation of communities near construction site, affect ecosystem.
Mexico: 4% of investment of renewable energy sources (2011). Potential capacity of 159 TWh annually. Current capacity of 11 000 MW, several projects lined-up with a capacity of 3,000 MW.

Sources: IPCC (2012), IRENA (2018), Autren (n.d.)

Geothermal Energy

Definition: Large scale geothermal energy generation.
Emissions: 50 gCO2e/kWh.
Costs: Investment vary depending on size of operation, current world examples are between 1,800 and 5,200 USD_{2005}/kW. From 2007-2014 LCOE varied from USD 0.04/kWh to USD 0.14/kWh depending on developments and geographical locations.
Potential Issues: Side-effect earthquakes when constructing, steam eruptions, high investment costs.
Mexico: 3% of investment of renewable energy sources (2011), currently 4 projects in Mexico, government support, currently 1.84% of total energy produced.

Sources: IPCC (2012), IRENA (2018), Meana (2014), Autren (n.d.), Petroquimex (2018)

Low Penetration Wind

Definition: Wind energy harnesses the kinetic energy of moving air. For low-penetration it has a penetration of the energy mix lower than 10%.
Emissions: between 8 and 20 grams of CO2 per kWh.
Costs: On-shore turbines have an average investment of USD_{2005} 1,750/kW. LCOE worldwide USD 0.06/kWh.
Potential Issues: Wind dependency, potential impact on bird's wildlife.
Mexico: 92% of investment of renewable energy sources (2011). Strong investment expected to be first in renewable energy generation in the country by 2033. Current main generation is concentrated in one state, Oaxaca.

Sources: IPCC (2012), IRENA (2018), OISE (2018), Autren (n.d.)

Coal CCS Retrofit

Definition: Using the process of Carbon, Capture, and Storage (CCS) on coal power plants by capturing the CO2 from the point source of exhaust gases.
Characteristics: There are 4 processes involved in CCS are: Capture, Separation, Transport and Storage of CO_2. For the retrofit option only capture (also the most expensive process) through post-combustion is possible. CCS technologies on existing coal plants achieved less than 45% in efficiency.
Emissions: Efficiency improvement in the range of 37-44%
Costs: an increase in the LCOE from 60-85 USD per MWh to 94-160 USD per MWh when having CCS technology. The cost for the installation of the technology vary depending on size, and age of the plant but the increase in price could potentially offset the costs in the long-term.
Potential Issues: high investment costs, new infrastructure installation, lacks policies for waste, carbon pricing.
Mexico: There are several Coal plants in Mexico, there are currently no plans of investing in refurbishing those plants with CCS. 16% of energy generation in the country comes from coal.

Sources: Lohwasser & Madlener (2012), CCUS Initiative (2018), Rubin et al. (2015), Solís (2019),

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Coal CCS New-built

Definition: Building a coal power plant with the inclusion of the CCS technology.
Emissions: Saving between 1.5 and 1.8 tons of CO2 per MWh.
Costs: an average size coal plant is estimated to be around 1.5 billion USD.
Potential Issues: High investment, continued dependency on fossil-based resources, contradiction with investment in renewable energy, pollution hazard, carbon pricing.
Mexico: expected new plant construction 2020. pending government approval. Investment of 840-1120 million USD for 2 units that will generate 700MW each.

Sources: Lohwasser & Madlener (2012), Rubin, Davison & Herzog (2015).

2.2.2 Forestry & Agriculture

Agronomic practices

Definition: Practices to improve soil quality, optimize use of water, handling of crops, and soil treatment improvement that are incorporated in the farm management system.
Emissions: Projected decrease of 0.2 tons of CO2e/hectare per year.
Costs: None in operation, potential education courses costs, learning curve could lead to reduction in profit at first.
Potential Issues: Change in lifelong practices, learning curve time, potential weather dependency.
Mexico: 50% mexican territory used for agriculture, crop production is 13% of the territory, accounts for 4% of GDP, 81% of their exports go to the US. Proposition of climate smart agriculture, techniques include silvo-pastoralism which involves a combination of harvesting crops and trees which then provide help with water and soil preservation, crop rotation, water harvesting, land levelling, and use of intercropping.
Sources: World Bank (2017), Santillán et al. (2016), Conservative Agriculture (2018), Robertson (n.d.), Adama (n.d.)

Reduced Deforestation

Definition: Reduction of forest and trees removal to be transformed to non-forest use (farms, urban areas).
Emissions: between 5.1 and 8.4 $GtCO_2$/year caused by deforestation
Costs: none in operation. Costs are associated when deforestation occurs which could hamper the environment and potential cost could rise to 17 billion for 1.5 $GtCO_2$/year.
Potential Issues: Agricultural needs, government policies.
Mexico: 54 million hectares classified as forest land, 22 million are commercial forest, forest grows from 25 to 30 million m3 of wood of which legally cut 8-9 million, illegally around 15 million is cut. Current programs: paid communities to preserve Mexico's forests. Mexico has the largest Payments for Environmental Services (PES) in LATAM. The PES is currently being used to finance 2 million hectares. Administration of the payments is by the National Forest Commission. It pays forest communities between 10 and 40 USD per hectare every year to preserve forests, payments may vary depending on the type of forest and the risk of deforestation.

Sources: WWF (2018), Greenpeace (2019), Eguiluz-Piedra (n.d.), Pagiola (2019)

Grassland Management

Definition: It is the handling, and manipulation of the land's natural vegetation in order to achieve certain objectives like increased grazing intensity, increased productivity, without using fertilizers, improve irrigating system for grasslands, and potential introduction of new animal or vegetation species.
Emissions: Projected decrease of 0.23 tons of CO2e/hectare per year.
Costs: none in practice, potential profit of 250 USD/hectare compare to conventional practice
Potential Issues: Learning curve for new methods, reluctance to learn new methods from farmers, potential weather dependency.
Mexico: the grassland in Mexico is representative of 40% of the country's total area. It is also a source of feed for livestock which accounts to 30% of the agricultural output. Constant environmental degradation, lot of grassland in arid conditions, lack of government support to enforce better practices.

Source: World Bank (2017), Santillán et al. (2016), Life Viva Grass (n.d.). SAGARPA (2017), Yáñez et al. (2018)

2.2.3 Waste

Electricity for Landfill Gas

Definition: Gas produced from large landfills that can be commissioned for electricity generation.
Characteristics: When material decompose, they produce what is typically called "landfill gas" which is made by 60% methane and 40% CO2. This gas is collected by drilling wells and then through pipes that transport it.
Landfill gas power plants reduce methane emissions, a global climate change agent with 23 times the negative impact of CO2.
Emissions: reduction of methane emissions, 0.15 reduction of kgCO2 per ton of waste compared to a conventional landfill. Added reduction provided by the energy generation.
Costs: around 9-15 USD/Kilowatt produce 9 KW per ton.
Potential Issues: Initial investment, not an established pricing for emission abatement electricity generation, lack of regulations, potential conflict of interests between investors and municipality where the landfill is located.
Mexico: there is an existing excel model, which was developed by U.S. EPA's Landfill Methane Outreach Program. It is used for estimating landfill gas generation and retrieval from waste landfills in the country. Lack of legislation, not enough investment, solid waste management system needs improvement.

Source: PACE Energy & Climate Center (n.d.), Broun & Sattler (2016), Davila & Stege (2009), Chen & Lo (2016), CTCN (n.d.),

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Waste Composting & Recycling

Definition: Sort solid waste for recycling purposes (organic, paper, glass, metal, hazardous, etc.). Waste composting is a bio-process with the compost ending as the result (can lead to further applications).
Emissions: on average between 0.2 and 0.3 tons of CO2 for every ton of waste, in comparison with the 1.3 tons of CO2 for every ton of waste that is currently emitted from landfills that do not have any treatment.
Costs: the costs vary greatly by country with some costs being around 5 USD per ton for low-income countries going to 90 USD per ton for high-income ones.
Potential Issues: Odor emissions of landfills, side production of GHG emissions (no methane) as it is an energy and fuel intensive process employing heavy machineries, education.
Mexico: trash only separated in organic and inorganic, compost plant outside Mexico City, only 33% of waste is being recycled, 38% of waste is organic, 42 million tons of trash are generated every year.

Sources: SEMARNAT (n.d.), Barclay (2009), Lou and Nair (2009), Hoornweg et al (2012), Sánchez et al. (2015), Cerda et al. (2017),

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2.2.4 Household

Lighting switch residential

Definition: Switching incandescent and compact fluorescent lamp (CFL) lighting for LEDs in residences.
Emissions: LEDs: 40% more efficient than fluorescent bulbs, 80% more efficient than incandescent lights. Potential of changing every home to use only LEDs could lead to 200 million tons of GHG emission reduction.
Costs: LED = 34 USD, incandescent bulb is just above 1 USD.
Potential Issues: high investment, light color change, long-term reflection on cost-savings
Mexico: plan to introduce regulations for energy consumptions in light bulbs, high starting price, only 18% of products are produced in Mexico.

Sources: Cowan & Daim (2011), Mills et al (2011), Ministry of Energy (2015), Hicks & Theis (2014),

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Solar PV panels for homes

Definition: Solar PV panels installed in residential houses. Energy captured by panels exposed to direct sunlight.
Emissions: None in operation, potential of 30-80 gCO_2e/kWh for chemicals derived from the panel installation and maintenance.
Costs: 2,000 USD 1kW module, 6,000 USD 4kW module. LCOE ranging 0.15-0.4 USD/kWh.
Potential Issues: home-owner investment, government permits
Mexico: 1% of investment of renewable energy sources (2011). Expected to reach 100,000 houses powered by solar PV. Installation costs have decreased 120% in 5 years.

Sources: IPCC (2012), Autren (n.d.), Solar Power Mexico (n.d.)

2.2.5 Transport

Air Transport

Definition: Alternative fuels/Bio fuels used to improve efficiency in the aviation industry.
Emissions: the aviation industry currently brings 2% of man-made emissions. Projections have the goal that with the aid of alternative fuels or bio-fuels by 2050 net emissions could be cut by half.
Costs: unknown regarding research and development, grants given in 2014 by the US government were of 210 million USD for the construction of bio-refineries to aid with the creation of bio-fuels.
Potential Issues: costs and supply related to alternative fuels, reluctance to change in the industry, unknown performance.
Mexico: Emissions of 6.62 mtCO2, 3,582 tons SOX and 70,007 tons de NOX (2010). Plan increasing fuel efficiency 2.2% annually until decreasing by 50% total emissions.

Sources: Ministry of Transport (2013), IATA (2014), Quant (2015), Ministry of Transport (2016), Higham et al. (2016)

Hybrid Vehicles

Definition: A hybrid vehicle has two systems in parallel, one is the electrical drive system and the other is the internal combustion engine. The electrical system runs when certain conditions are being met, this provides relief to the ICE and optimizes gas emissions.
Emissions: Hybrids produce 2.7 tons of CO2 every year, for comparison a gasoline car is producing 5.4 tons of CO2 per year.
Costs: average starting price of 33,000 USD depending on the car.
Potential Issues: Higher initial investment compare to petrol cars, low range of full-electric driving.
Mexico: upward trend of buying hybrid vehicles, incentives to buy car, not a wide range of models.

Sources: AFDC (2018). Ordaz (2019)

Battery-Electric Vehicles (BEV)

Definition: BEVs are electric vehicles that use solely energy provided from a charge station (electricity) this energy is transferred from the charge station to the battery packs. They do not possess an internal combustion engine, but rather an electric motor for propulsion.
Emissions: BEV produce 2 tons of CO2 every year, for comparison a gasoline car is producing 5.4 tons of CO2 per year.
Costs: the average BEV cost is 35,000 USD, but the price can vary depending on the brand and model.
Potential Issues: Higher initial investment compare to petrol cars, dependent on charging stations infrastructure.
Mexico: upward trend of buying electric vehicles, not enough charging stations, sold in main cities, incentives to buy car, not a wide range of models, some free charging stations.

Sources: ScienceDaily (2018), Alternative Fuels Data Center (2018), Tesla (2018). Ministry of Foreign Affairs (2019)

Modal Shift Freight Transport

Definition: Optimization of operations on how freight transport is delivered (earth, sea, air).
Emissions:

Modality	CO2 Emission (g/t-km)
Semi-trailer truck	Between 60 and 80
Truck of between 10-20 tons	Between 120 and 150
Electric train	Between 30 and 40
Diesel electric train	Between 35 and 45
Ship capacity 250-1K tons	Between 35 and 70
Ship capacity 1K-3K tons	Between 30 and 55

CO2 emission factors by freight transport mode (Essen et al., 2003).

In the US it is expected that a good optimization in the freight transport can lead up to 25% reduction in overall emissions.

Costs: varies greatly if infrastructure is needed in the country, carbon-based fuel price depending on the means of transport.

Potential Issues: Fuel costs, transport industry conflicts of interest, infrastructure

Sources: Essen et al. (2003), TNO (2018), International Transport Forum (2014)

Transport Policy changes

Definition: Optimization in transport use, restrictions of high emission transport, vehicle limitation use by regulation, import car reduction.

Emissions: approximately 1.3 GtCO2 worldwide from road transport in 2016.

Costs: costs of operations for enforcing regulations

Potential Issues: lack of alternative means of transport, change reluctance from population.

Mexico: car ownership expected to hit 30 million cars by 2030, long commutes from home to work in main cities (low residential density & high downtown employment density), promote sustainable urban mobility model for the country. Current Band-Aid when air pollution is high government enforces cars to not be used in certain days depending on plate numbers.

Sources: Rebolledo (2016), WHO (2018), World Bank (2017)

Heavy Duty Vehicles (HDV) emission reduction

Definition: target reductions in fuel consumption, carbon dioxide, or greenhouse gas emissions for HDV

Emissions: Around 25% of road transport emissions. Around 0.3 GtCO2 worldwide.

Costs: R&D related costs, fuel costs, alternative fuel costs
Potential Issues: increase in road freight transport, lack of regulations
Mexico: lack of regulations when manufacturing HDV until 2021, most of them are exported to the US which has regulations. Big manufacturing industry. Government norm NORM-044-semarnat-2017.

Sources: EC (2018), Ricardo Energy & Environment (2017), SEGOB (2017)

Light Duty Vehicles (LDV) emission reduction

Definition: target reductions in fuel consumption, carbon dioxide, or greenhouse gas emissions for LDV.
Emissions: Around 50% of road transport emissions. Around 0.6 GtCO2 worldwide.
Costs: R&D related costs, fuel costs, alternative fuel costs, SEGOB (2013)
Potential Issues: Lack of regulations, increase in vehicle costs.
Mexico: Old regulations (2004), most of the vehicles are for exportation they have to comply external measures, lots of companies manufacturing in the country.

Sources: US EPA (2019), EC (2018),

2.3 Chapter 2 Conclusions

The main objective of the chapter was to answer the question *"What are the relevant abatement options needed to reduce GHG emission in Mexico?".* A selection criterion was performed using the available information materials. It must be noted that this step is the foundation of the research, given that the abatement options selected were investigated thoroughly throughout the whole thesis process. The question above was answered by selecting 20 abatement options that are deemed as relevant for Mexico's current affair and the investigation of this should help in understanding how to reduce the GHG emissions of the country. This chapter then focuses on examining the abatement options by sector and give exploring their implementation costs, potential of GHG abatement, what Mexico is doing, among others.

SECTION 3
Preliminary Y-curve

CONTENT

3. Preliminary Y-curve

3.1 Scoring of Abatement Options

3.2 Preliminary Y-curve

3.3 Chapter 3 conclusions

03.

3. Preliminary Y-curve

This chapter aims to provide an overview of the scoring of the abatement options selected in Chapter 2 applying the Y-factor method. These scores are based on information gathered from scientific and news articles, and government reports. Therefore, the results at the end of the chapter are meant to be used as the starting point of information for future chapters and the scores will be used as a starting point for interviews with field experts that are presented in Chapter 4.

3.1 Scoring of Abatement Options

This section has the purpose to showcase the scoring of the abatement options selected, the information used for the scoring is presented in Chapter 2. The main purpose of this section is to depict the reality with the current situation in Mexico; even though an accurate number is ideal expert interviews will also add information in Chapter 4 which could lead to changes on the scoring and the subsequent Y-curve. As a remainder the Y-method grading is meant to notify the degree on which each socio-technical factor affects the implementation of the abatement options while the scoring in comprised by 0, 1 and 2. For easier identification of the abatement option with the highest degree of difficulty several charts have been made which are divided by the different socio-technical clusters of the Y-factor: *Figure 3* represents the Cost & Financing cluster, *Figure 4* the Multi-actor complexity cluster, *Figure 5* the Physical Interdependences, and *Figure 6* the Behavior cluster.

3.1.1 Cost & Financing

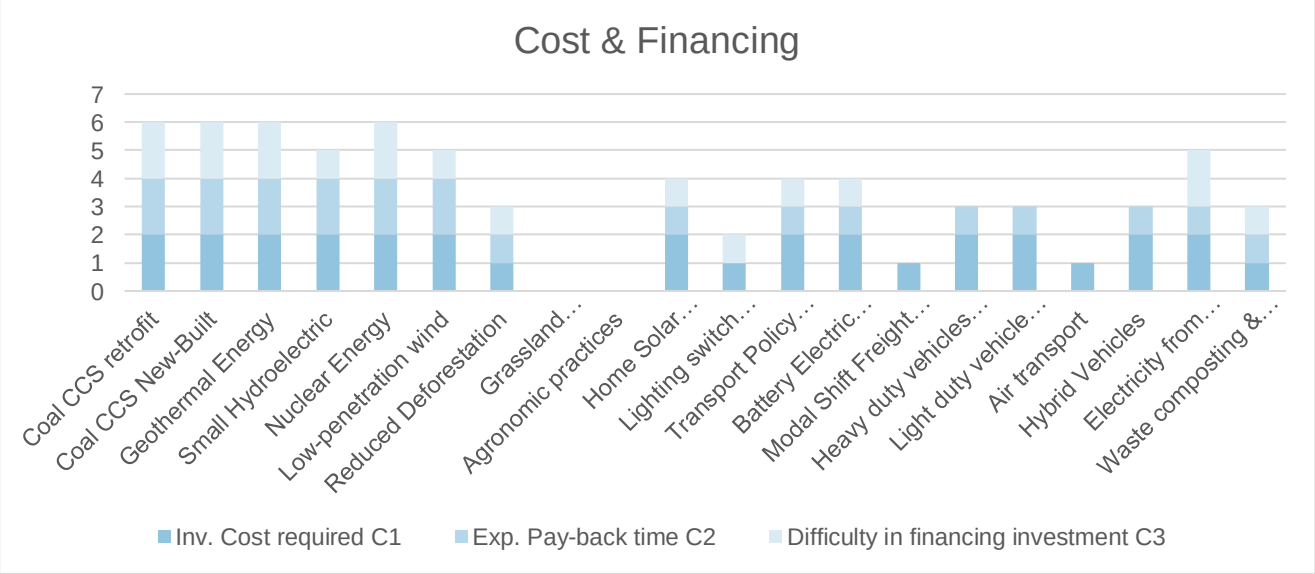

Figure 4: Cost & Financing chart

Energy

The energy cluster involving the abatement options of nuclear energy, geothermal energy, low-penetration wind, hydroelectric, and coal CCS new-built have been graded under the premise that

they need to have new plants built. A score of 2 for investment cost required is being given to all these options. Under the same line of reasoning the amount that must be spent to have your return of investment is been set at more than 12 years, this is because of all the changes that need to infrastructure that needs to be built for the new energy plants. Meanwhile low-penetration wind and geothermal energy have a less timeframe for the expected payback time but a lack of infrastructure to transport the energy that is been produced through these methods also pegs back the payback time beyond the threshold of the 12 years. The difficulty in financing investment was set given current market conditions, with banks more likely to give loans to renewable energy measures such as low-penetration wind and hydroelectric, both options are set at medium difficulty while the other energy options are highly difficult to find investors for the given options.

The analysis for the scoring for the Coal CCS retrofit is considered to have high costs for implementing the CCS into a coal plant and a lack of certainty in how long it will take to recover the investment. Both factors make it a foregone conclusion that the difficulty in finding investment will also be high. All these measures have been set with a scoring of 2.

Forestry & Agriculture

In this cluster the view for agronomic practices and grassland management is quite similar even though they are different options. It is believed that to improve both of this abatement options the cost involved are low with good potential results in higher yield crops and better nutrients in soil that will yield more profit to the owner of the land. The grassland management option also relies on the reduction of using chemical components into the grassland further decreasing the costs involved in the process. Therefore, both factors are ranked with a 0 in investment cost required and expected payback time. For the difficulty in finding investment the premise is that it is non-relevant given the low-cost attached to the operation making it also a score of 0.

For the reduced deforestation option, the investment cost required is scored as medium, this is because must of the forest are in areas that are not easily accessible meaning that the investment should go to the vulnerable areas making it a medium investment. Also, the payback time of that investment is between 5-12 years considering that the illegal logging will go down gradually if efforts to safeguard the forests are implemented. The difficulty in financing investment is a 1 considering that the costs to cover the operation should not be high and there should be a willingness to reduce the illegal logging of the forest.

Waste

The investment cost required for Electricity for landfill gas is set at 2 cost of the changes and constructions that need to be done for this to be a feasible abatement option. Considering the size of the landfills in the outskirts of the big cities the payback-time is considered to be between 5-12

years, while the difficulty is financing investment is high given that in case of been pursued is a new project in the country and the results of the investment are unknown.
The waste composting & recycling option has the factor C1 as a 1 because the principles of recycling are already in place, but further investment is needed to maximize the potential of this initiative. This option is also expected to take more than 5 years to recover, hence the score of 1 for C2 and the difficulty in financing investment is set at 1 because the government has pushed for this option to be further analyzed but until now it has not been done in a high scale.

Household

The lighting switch has an investment cost of 1 given that the actor doing the change is the home-owner and the average income in Mexico is low enough that this change could alter a household budget in the short term. The expected payback time is set at 0 given the saving in new lightbulbs that buying LEDs can provide. C3 is set at 1 because there are no added incentives to change to LEDs and lightbulbs are cheaper in the short term.
The Solar PVs have a C1 score of 2 because of the investment required by the homeowner considering installation and material costs. The payback time should be between 5-12 years depending on the saving generated and which is the use that the solar PVs are being used for (electricity, heating). Meanwhile C3 is set at 2 because the government does not provide any subsidy for trying to change to a solar powered home.

Transport

Modal Shift Freight Transport is considered to be have high investment cost require because it needs to re-plan the way that freights are been handled, this leads to a lot of money spent on logistics. The C2 factor is a 0 because the payback should not take long to cover with the optimization of the supply chain and given the importance of the freight transport in the country it is assumed that there will not be an issue in financing the investment.
The transport policy changes also have a 2 for the investment cost because it involves revamping city plans, changes in the way public transport is been handle and even constructions of new stations or added public transport capacity. The payback time depending on the amount of public works varies so a score of 1 is given. Given the importance of transport in big cities it is expected that the financing should have a medium difficulty to find.
For the HDV and LDV emission reduction are similar in terms of their costs and financing involved so it is assumed that the scores for the factors in this cluster will be the same. They have a score of 2 for C1 given the costs of research and development that need to be made to improve the emission reduction. The payback time is a 1 because more environmentally friendly cars should have more sales and even though the initial investment is high it should be replenished in less than 12 years.

In addition to this, the difficulty in financing investment is set at 0 considering the size of the industry and the current trends in investment.

For the environmentally friendly cars such as the BEV and the Hybrids C1 is a score of 2 because a private person is doing the investment and it is assumed that it is high to buy a new car for any household. The expected payback time for the investment is set at 5-12 years considering the reduction of expenses in fuels. At last the difficulty in financing investment is 0 for the hybrids because there are some social benefits when buying this type of car, while the electrics have a 1 because it is not a widespread market in the country.

For the Air transport the investment cost is set at 1 because it is believed that the industry is big enough for the investment in alternative fuels to be medium in comparison with the size. The payback time is 0 because of the amount of save fuel or improvement in efficiency that a new development can lead to and the difficulty in financing is also 0 because of the popularity of the industry.

3.1.2 Multi-Actor Complexity

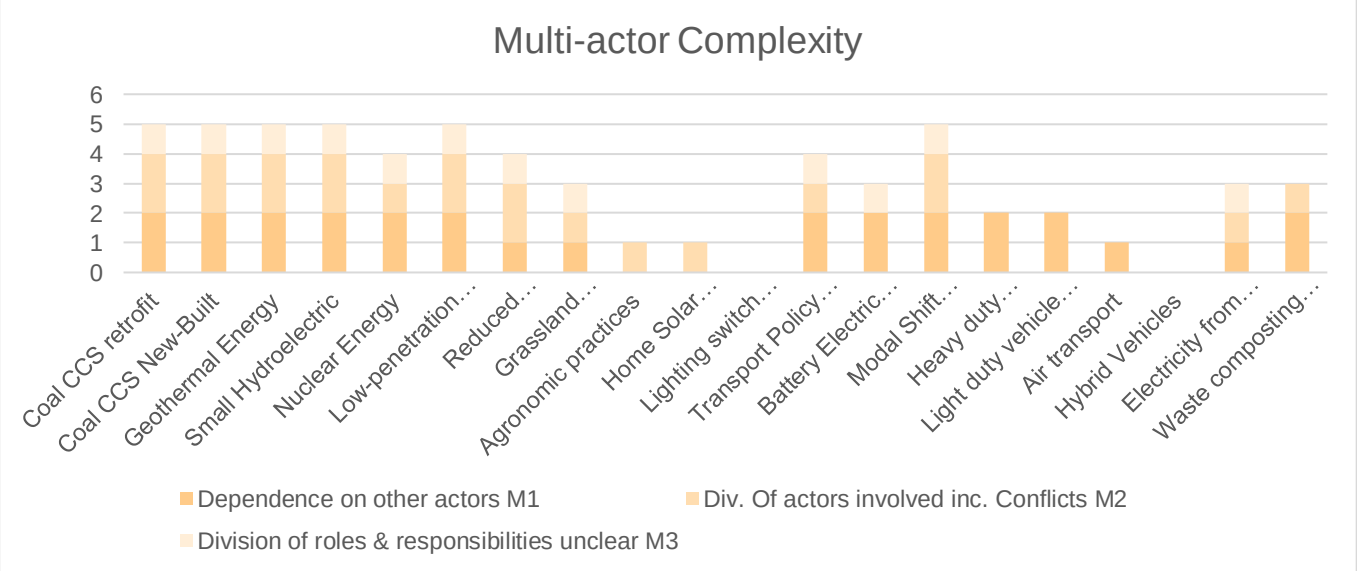

Figure 5: Multi-actor complexity chart

Energy

For the abatement options related to energy all of them are given a dependence on other actors' grade of 2. This is due to the fact that even though the energy is being produced in the energy plants the Mexican government utilizes a centralized way of distributing energy through the Federal Electricity Commission making the renewable energy providers and the Coal energy dependent on this commission. For the division of actors involved including conflicts factor, all of the scores in the energy sector are also ranked as 2 minus the nuclear energy. This is because given the centralization of the distribution of energy in combination with the dependence of using fossil-based energy it is unclear which percentages must be paid to the commission to transport the energy or if the private

parties who own any energy plant are responsible of building their own transport infrastructure as well as setting the prices for the energy generated making it a clash of their respective interests between government and private enterprises. Nuclear energy is considered to have a lesser issue in these factors because the way nuclear plants have work in the country already have relations between the government and the nuclear plant. In addition, the factor “division of roles and responsibilities unclear” are set as 1 given that there is somewhat of a gray area between the actors involved and what each of them needs to do.

Forestry & Agriculture

The reduced deforestation option is given a score of 1 for the dependence on other actors given the involvement of government officials and communities to safeguard the forest. The score for M2 is given as a 2 because there is a contradiction in some states in attracting foreign investment through industry or any other activity and also not been able to use the forest land, so it is a clash between developing a city, industry, etc. or keeping the forest. Meanwhile for M3 is also considered a 1 because the actors involved does not have enough clarity on their activities to keep the forest.
For agronomic practices M1 is considered to be a 0 because the owner is the one that decides the method and type of crop that they are going to cultivate giving him freedom to do what he wants and avoiding depending on other actors. There could be some misunderstandings when between producer and buyer in which crops to produce and this could cause some conflict between them, that is why M2 is considered to be a 1. For the responsibilities they are clear for the parties involved and they are also a 0.
For the grassland management option M1 was rated as a 1 because they might depend on other actors to help them with preserving the grassland, this can be by having external workers or depending on other persons in their day-to-day activities or to teach them the best practices. There can be conflicts between actors in this option because it relies on the owner cutting pesticides and chemical enhancers and this could lead to some disruptions on how the grassland will react and some unforeseen consequences. Meanwhile division of roles can be somewhat unclear when dealing with new methods and that is why a score of 1 is given.

Waste

For the multi-actor factors, the option electricity of landfill gas lands the same score of 1 across the different factors. This is because this option is somewhat dependent on other actors, like trash operators, government and communities to have a successful project, there could be conflicts because the landfills are in municipalities that are different from the cities that actually produced the trash and the income generated for the electricity will be wanted by the city, as well as, the municipality where the landfill is located. Finally, the division of roles is somewhat unclear given the

same issues that a lot of actors are involved, and state, municipalities and city government will be part of the discussion of which responsibilities are for which actor.
The waste composting & recycling relies the most in the people from the cities because they are the ones that generate the trash and if the government does not put in place a recycling program and different containers for garbage the persons will not separate the trash and the recycling part will be really hard to achieve, hence a score of 2 is given. The factor M2 has a score of 1 because, as in the case of the landfill the trash generated ends up in different municipalities and the benefits of recycling and the potential income for the composting and the recycling could lead to some conflicts between actors if there is no government intervention.

Household

The lighting switch have the same score along all the multi-actor complexity factors because they are not dependent in any way on another actor making all the scores 0. The home solar PVs are not dependent on other actors giving them a score of 0 for M1 and also a score of 0 for M3 because there are no other actors responsibilities involved. For M2 it is set at 1 because it is possible that the Federal commission is still supplying electricity to the household and could be losing clients by the installation of the solar PVs in the houses that is why a score of 1 is given.

Transport

Air transport does not have to deal with conflicts or unclear responsibilities so both of the scores for M2 and M3 are a 0; while they are somewhat dependent on other actors mainly because a potential breakthrough could come from a lab in a university or some discovery in another industry.
The modal shift in freight transport is a complex abatement option that relies on total commitment from all the different transport sectors involved this causes to be the most complex option of the cluster where a score of 2 for every factor is given. The option of transport policy changes also deals with a lot of actors involved, namely community, public transport, private persons, school and work schedules so it is highly complex and depends on multiple actors so a score of 2 is set. Meanwhile the government is the deciding actor and therefore could enforce changes without much reluctancy from other actors that is why M2 and M3 is considered to be a 1.
For HDV and LDV they mainly depend on R&D departments to be successful as well as being dependent on government or industry policies to set limits for the emissions that could derail or make a change for the industry to improve the manufacturing of cars and trucks. There should be no conflicts because they all want to increase the efficiency because that will lead to cost reduction so a score of 0 is given.

The hybrid vehicles are considered to be as normal vehicles, so they do not depend on any external actor to work, automatically giving a score of 0 across all the multi-actor complexity factors. Meanwhile BEVs

3.1.3 Physical Interdependence

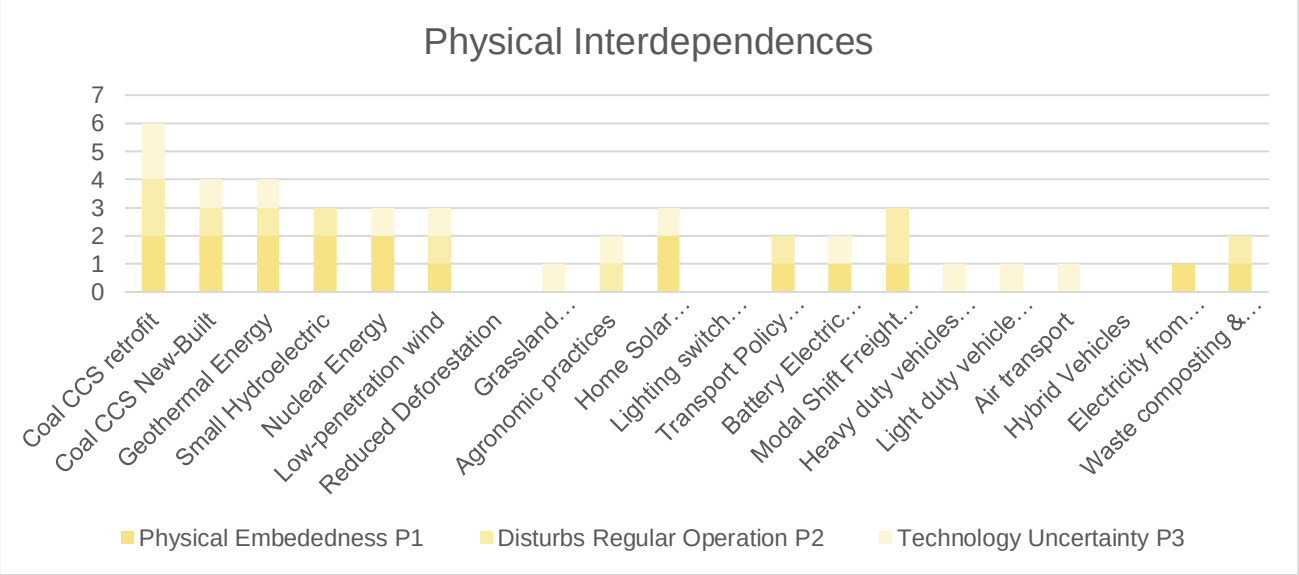

Figure 6: Physical Interdependences chart

Energy

For the abatement options that are part of the energy cluster it is considered that since almost all of them need the construction of a new plant the physical embeddedness associated with it should be a 2 given all the changes that need to happen on-site for it to be done. The exception is low-penetration wind with a score of 1 where the installation of the turbines is less damaging to the physical space were they are placed. For the factor “disturbs regular operations” the coal CCS retrofit has a score of 2 because the plant needs to stop, at least partially depending on size to have the proper installation of the new features. For the other types of energy generation, the score given is a 1, this is because the activities that were held on the potential sites of construction will have to be displaced to another part; in the case of the hydroelectric the displacement of communities can be involved. The technology uncertainty is present in all the energy options in some measure, this is because there is always uncertainty on the way the renewable energy captures and stores energy and development for increasing plant efficiency is always improving. The same example of efficiency can be said for energy plants that rely on coal, or nuclear power where there is room for improvement that is why the scores for this factor are set at 1. For the Coal CCS retrofit it is harder to measure the improvement of the technology and that is why the uncertainty ranks with a 2.

Forestry & Agriculture

For the reduced deforestation option, the notion that all 3 factors for physical embeddedness are given a 0 is because this option relies on preventing any change in the physical environment making all of the options automatically a 0. For grassland management and agronomic practices there is kind of uncertainty in the new methods that are going to be used because sometimes they are not been tested in the same conditions as the ones that are going to be implemented giving them a score of 1 for both options. The physical embeddedness should stay the same or really close to it making it a 0 for both options. The grassland management should not suffer for the disturbs of regular operation, but the agronomic practices might change given the new methods that can be implemented that is why a score of 0 and 1 is given respectively.

Waste

For both abatement options of the waste cluster the physical embeddedness was set at 1 because there going to be slight changes in the space where the garbage is. Meanwhile the technology uncertainty is set at zero also for both because they are proven methods that have been used in small scale projects in other parts of the world. Meanwhile the electricity from landfill is not expected to disturb any operation but the waste recycling could lead to changes in the average day-to-day activities given that separated trash could cause different logistic measures for garbage trucks in how to cover the city.

Household

The switching lighting abatement option does not have any change in the physical environment of the house as it is just to change the lightbulbs for LEDs, thus a score of 0 is given across the factors. The home solar PVs will change the outlook of the home in a major way because of the installation of the panels therefore a score of 2 is given in that factor. The solar PVs should not affect the regular activities of the household and therefore the score is 0 for P2. Meanwhile the technology uncertainty is set at 1 because the efficiency on which the solar PVs capture energy room for improvement but it is still functional to provide heating of water of supplying energy for the household.

Transport

The HDV and LDV vehicles options, as well as, the air transport does not have any physical embeddedness so a score of 0 is given, they also do not disturb the operations (0), and have a score of 1 for technology uncertainty because as is the case in every technology it has not been proven and the industry does not know the potential side-effects of it.

The use of Battery Electric Vehicles will change the physical environment because charging stations need to be installed but this should not interfere with regular operations in a city trip. The technology uncertainty is also a 1 considering the low amount of years that the electric vehicles have been running. Meanwhile hybrid vehicles will not change the physical space and will not interfere with regular operations making them a 0 for these factors by default, technology uncertainty is also set at 0 because they still rely in fuel-engines and the vehicle should not have issues working.

The modal shift transport is expected to somewhat change the physical environment of potential new infrastructure for connections between the transport modes that could be built, and it is assured that a new plan will result in delays and disturbing of the regular operation that is why a score of 2 is given.

Transport policy changes has a score of 1 for P1 because they could change the landscape of the city by adding public transport stations or developing a new system to optimize the current transport network. A score of 1 is also given for possible disruptions in the regular operation because it is likely that there are some people that will be affected by the changes imposed, it is not considered a 2 because the city has sufficient means of transport to be capable to only suffer minor disruptions.

3.1.4 Behavior

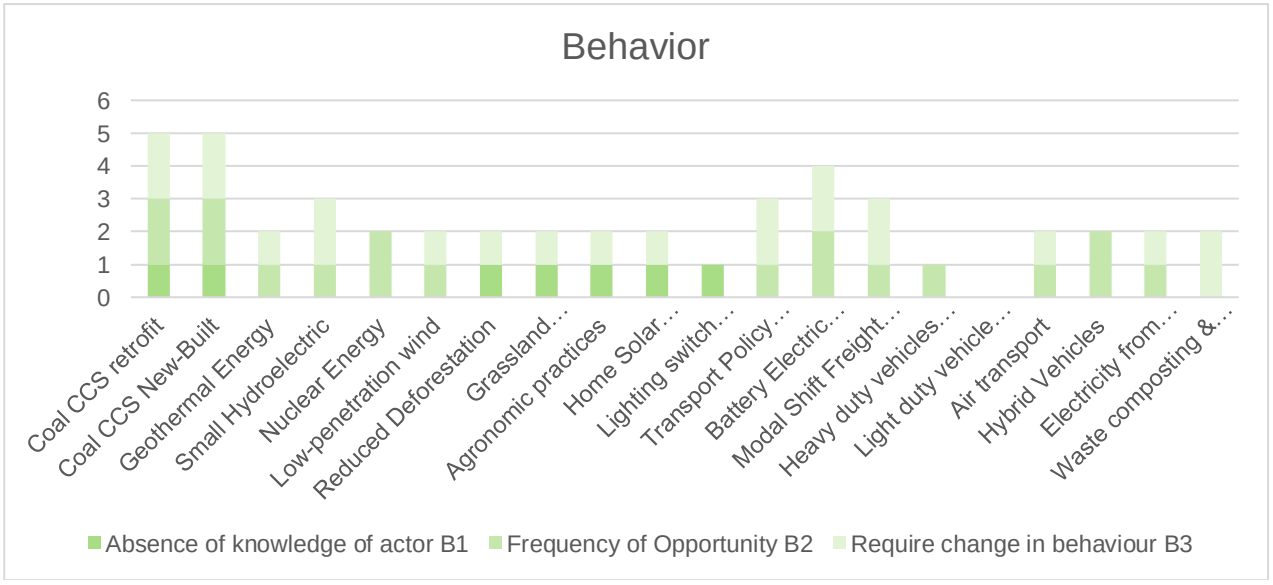

Figure 7: Behavior chart

Energy

For the energy cluster it is considered that the actors taking the construction of the energy plants is knowledgeable in the topic making it a 0 for the factor. This is not true for the CCS abatement options, this can be explained by the continuous improvement in efficiency for a coal plant and also the CCS option makes them a new technology so not everyone can understand the in-depth features of the technology; a score of 1 is given. The frequency of opportunity is ranked as a 1 for the geothermal,

wind, and hydroelectric energy because of the locations available to install these types of energy considering the geographical space of Mexico. For the Coal CCS options, the frequency of opportunity is much less given the limited number of plants that are for the option to be implemented and the pre-defined construction of the CCS, thus making it a 2. For the change in behavior the CCS options are considered to change because of the new technology implemented and the potential changes in how the coal plant used to operate. For the nuclear power since it is a new plant there is not a change in behavior while for the renewable energy options they are consider changing slightly since it's a different way of producing energy that what the society is used to and this leads to some changes to adapt to the different characteristics of these types of energy.

Forestry & Agriculture

For the agronomic practices and the grassland management the absence of knowledge of actor score of 1 is given because normally the owner knows the methods that they have been using from a long time so to change methods to improve either option makes it less likely to have a full knowledge of the situation. The frequency of opportunity of both abatement options is been set at 0 given because they could alter the way they operate when they decide to do it. A change in behavior is going to be likely for both options and that is why a score of 1 is given.
For the reduced deforestation option B1 is given as a 1 because normally the "guardian" of the forest are the communities where the forest is located and normally this communities does not have the level of education to properly prevent and take care of the forest in the best way. The frequency of opportunity is 0 because there are still large amounts of forest in the country, although this factor could be altered rather quickly is an increase in logging happens for a sustained period of time. For B3 there should be a change in behavior on how we continue to exploit these resources and that is why the score is 1.

Waste

For the behavior factors, both options from the waste cluster are expected to suffer changes in their current behavior. For the electricity of landfill gas it should be minimal, and the behavior will change for safety measure of the people working at the landfill, while for the waste composting & recycling the changes are more drastic because it will involve separating in certain ways the trash for the population and also could change garbage trucks schedule for collecting organic, or inorganic trash. The frequency of opportunity is set at 1 for the electricity from landfill option because there are limited amounts of landfills and could be the case that the trash will get removed or use in a different way or with a different purpose than to generate electricity that is why a score of 1 is given. For the recycling and waste composting option B2 is set at 0 given the multiple opportunities available to run and teach recycling programs. Both of the options were scored with a 0 for B1 because the

knowledge required to implement this abatement option should not be specialized and should be easy to comprehend.

Household

The absence of knowledge of actor for the lighting switch changes is considered to be medium given that the buyer itself will probably will be buying the LEDs for the savings benefits, the frequency of opportunity is 0 because the change can be made at anytime and it does not require any change in behavior for the use of lights in the household.
The home solar PVs also can be changed at any time so the frequency of opportunity is 0, while B1 is 1 because the buyer will probably will not know the ins and outs of the technology, and it may require a change in behavior, score of 1, mostly during do the day when the solar PVs are gathering energy and could be store for the night or depending on the seasonality of the hours of sun in the year.

Transport

The air transport is believed to be well knowledgeable in the new developments in the industry that is why a score of 0 is given for B1. Meanwhile the development of a new bio-fuel or alternative fuel could disrupt current behavior and potentially require some changes that is why a score of 1 is given and the frequency of opportunity of believed to be 1 because new developments in fuel are not easy to adapt if it requires changes to the design of the aircraft.
The modal shift transport has a B2 score of 1 because it involves different transport sectors that are constantly evolving, and this could lead to opportunities being somewhat scarce to make a unified front for the freight transport. A change in behavior is imminent is this option is to be pursued so a score of 2 is given.
The transport policy changes will also require a huge effort for the actors involved and a change of the current behavior is imminent regardless of the policies that can be designed, a grade of 2 is given for B3. The frequency of opportunity is set at 1 because it involves permits, government, and allocation of money to be involved to pursue any change and this make the opportunities to implement it slightly decrease. The actors are considered to have enough knowledge to make decisions regarding any change in transport policies.
For the HDV and LDV it should not require a change in behavior so both scores are set at 0, while the frequency of opportunity is not relevant for the LDVs, the HDVs are dependent on stricter regulations that could affect the schedule for doing changes. Both actors are considered to have knowledge of the situation, so the scores are also set at 0.
For BEVs there needs to be a change in behavior because the user always must make sure that the car is charged for optimal use. Meanwhile, the frequency of opportunity to buy a BEV or Hybrid

vehicle is low because when a household purchase a car is highly unlikely that they will purchase another one making it decrease the opportunity of acquiring anyone of these types of cars. Both actors are considered knowledgeable and conscious to make the purchase of a battery electric car or a hybrid car, so the number is set at 0.

3.2 Preliminary Y-curve

Figure 7 showcases the preliminary scores that were assessed doing the literature review. The Y-score is provided with the totals of each abatement option with the highest score meaning the most difficult abatement option to pursue, while the lowest scoring can be categorized as the abatement option most likely to have success. The chart is good for portraying a picture of all the scores and quickly evaluating which are the best option. Nevertheless, if an in-depth analysis is required the figure "Y-score by factors" has all the abatement options with the scoring of each factor in the same figure, thus making it useful to see which cluster of factors is hampering the most any given option.

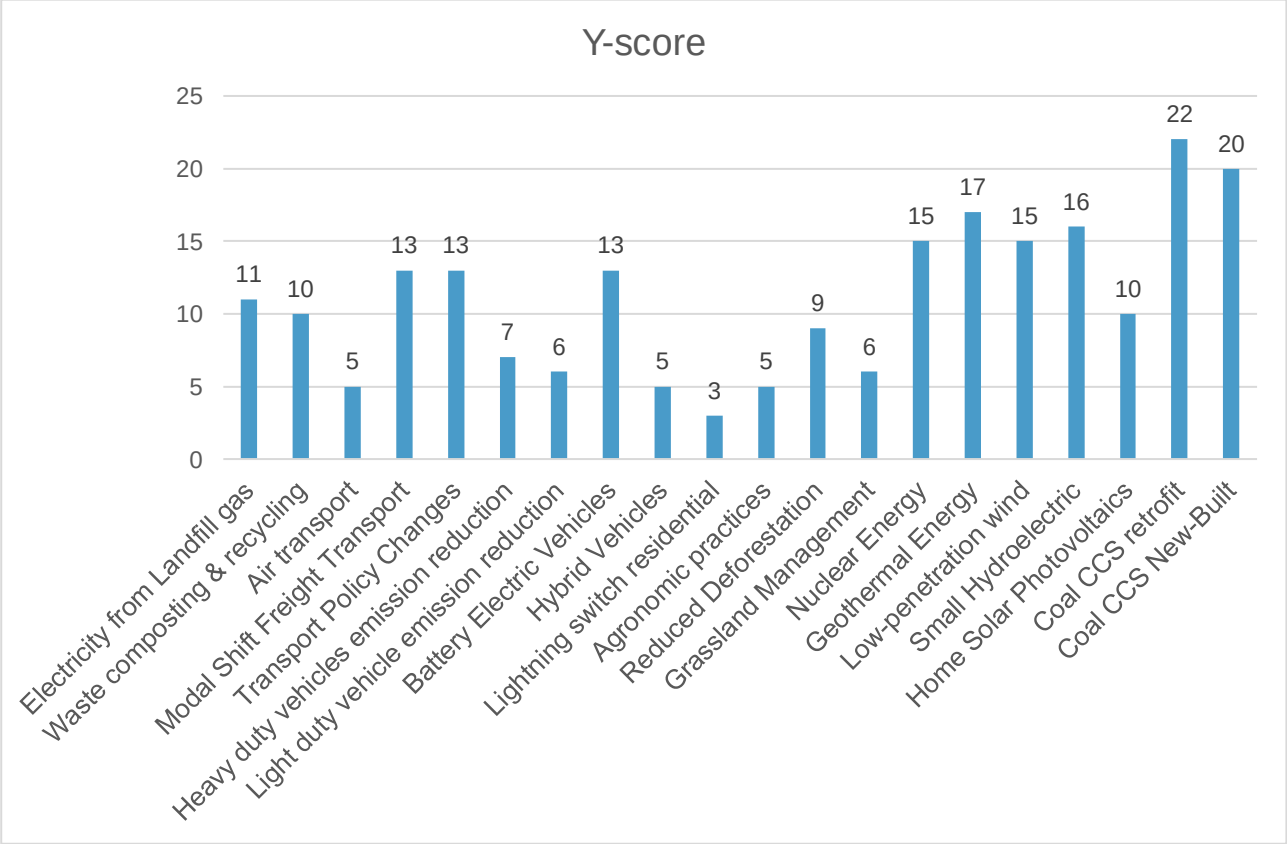

Figure 8: Preliminary Y-score chart

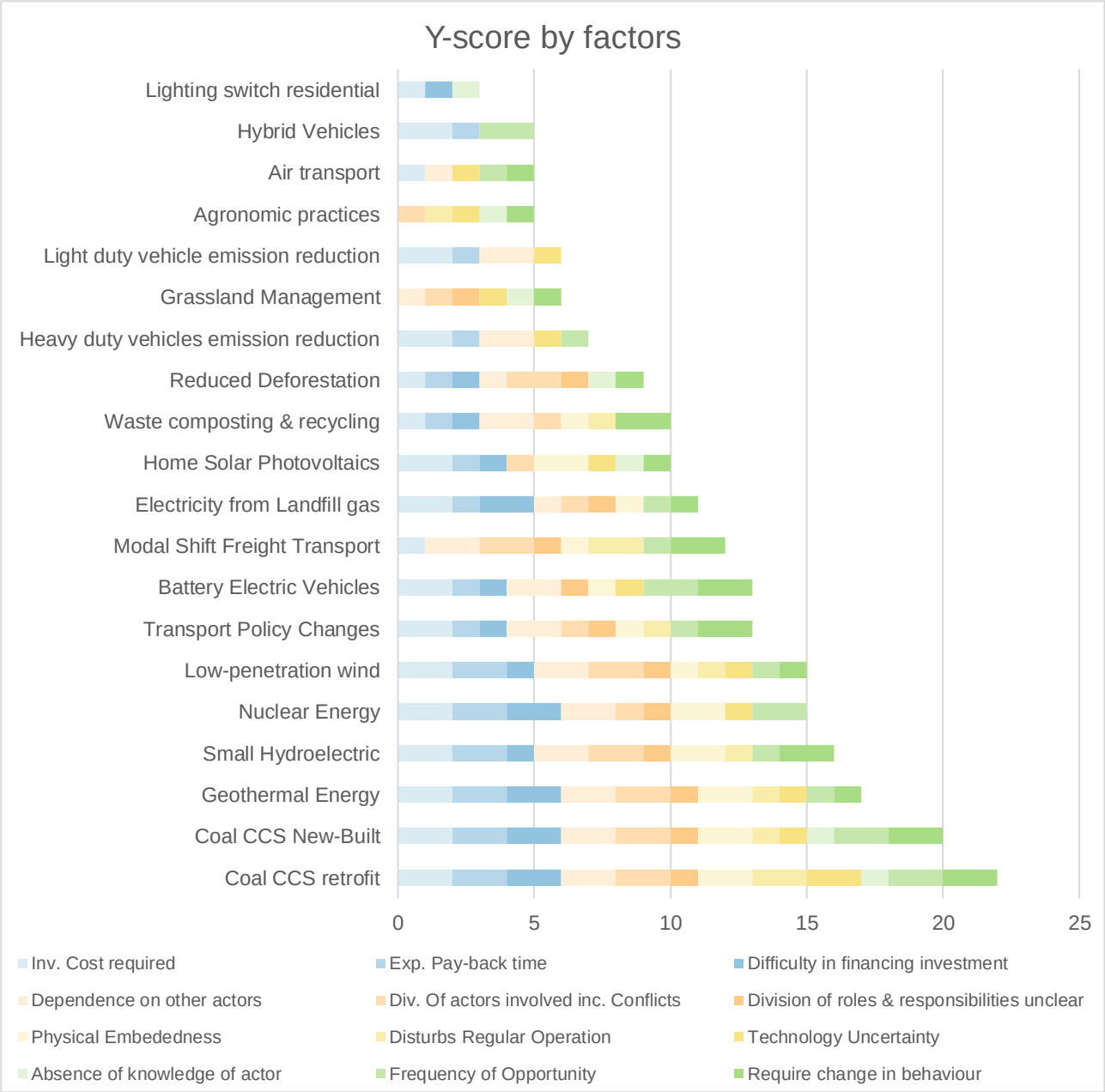

Figure 91: Preliminary Y-score chart disaggregated by factors

Figure 8 is the graphical representation of the scores provided in the preliminary assessment. They have been divided by clusters, with a different color representing each of them and by factor with a different shade use for clarity of what each factor score is. This is a table that is useful when having to perform an in-depth analysis of how each abatement option performed in any given cluster of the Y-factor or as an overall grade.

3.3 Chapter 3 Conclusions

The chapter focus was on understanding which socio-technical factors using the Y-factor method affected the potential implementation of the abatement options in Mexico. The sub-question for this is *"How can the Y-factor method identify the barriers that are hampering the implementation of the selected emission abatement options?"*. The question was answered by scoring through literature

review each abatement option on the 12 barriers of the Y-factor method, the options that received the highest scoring are considered to be the most difficult to pursue given their overall score. Figure 8 depicts how each abatement option fared by total score, cluster score and individual factor score. This makes it easier to read and comprehend with barriers are interfering with the abatement option implementation. The reasoning for each scored is explained throughout the chapter to understand the score behind it. In conclusion, this chapter is meant as a stepping stone for portraying the reality of this abatement options in the country, but it is meant to be informative and is subject to change, if needed, when experts' opinions are considered.

SECTION 4
Validated Y-curve

CONTENT

4. Validated Y-curve

4.1 Interview procedure

4.2 Interviewed experts

4.3 Interview Results

4.4 Validation Process

4.5 Validated Y-curve

4.6 Chapter 4 conclusions

04.

4. Validated Y-curve

This chapter focuses on the validation on the preliminary Y-curve provided in Chapter 3. It builds on the outcome of expert interviews and how the results contributed in the creation of the validated Y-curve. The section is structure into sub-sections that will guide the reader through the process of the validation of the Y-curve starting with how the interviews were performed (4.1), the name of the experts who provided the feedback from the preliminary Y-curve (4.2) and the subsequent scores with the comments that were made regarding the scoring of the abatement options (4.3). The chapter ends with the validation of the Y-curve represented in a graph (4.4).

4.1 Interview procedure

To increase credibility and certainty to the Y-curve previously constructed, a group of experts (*Table 3*) were contacted to pursue a one-on-one interview to give their opinions about the abatement options selected. These experts were selected given their knowledge of the energy market and were paired according to their knowledge expertise of specific abatement options (*Table 4*).

Each expert was asked for an interview of around 1 hour (times were adjusted depending on availability) and was provided with the list of abatement options from Chapter 2 and the list of socio-technical factors from which they were going to be graded.

All the interviews started with a summary of the purpose of the interview and a demonstration of how to grade the abatement options was presented. The interviewee was responsible for adjusting the scores provided in the preliminary assessment from Chapter 3 and giving supportive arguments for changing the scores. The interviewee was also encouraged to discuss any added information that could help have an accurate grading of the abatement options. Interviews were made in Spanish to facilitate communication in their native language, then were subsequently analyzed to validate scoring and to have a clear understanding of what the experts wanted to communicate. Each interview was translated to English with the most important arguments, complete tables of interviewee names and notes can be found in Appendix B.

4.2 Interviewed experts

Expert	Affiliation
Fernando Canut	IBERDROLA Mexico
Edgar Fabris	Ministry of Transport (SCT)
Jorge Escobar	Ministry of Transport (SCT)
Ximena Celis	Ministry of Environment & Natural Resources (SEMARNAT)
Interviewee A*	University of Groningen
Interviewee B*	Durham University UK
Antonio del Río	National Autonomous University of Mexico (UNAM)
Edgar Rubí	Ministry of Energy (SENER)

Table 3: Experts & Affiliation

*Interviewees A and B have decided to maintain anonymous their names for this research but are willing to show their current affiliation.

Sector	Abatement Option	Interviewee 1	Interviewee 2	Interviewee 3
Waste	Electricity from Landfill gas	Fernando Canut *(IBERDROLA)*	Int. A *(University of Groningen)*	Int. B *(Durham University)*
Waste	Waste recycling	Fernando Canut	Int. A	Int. B
Transport	Air transport	Edgar Fabris *(Ministry of Transport)*	Jorge Escobar *(Ministry of Transport)*	
Transport	Modal Shift Freight Transport	Edgar Fabris	Jorge Escobar	
Transport	Transport Policy Changes	Edgar Fabris	Jorge Escobar	
Transport	Heavy duty vehicles emission reduction	Edgar Fabris	Jorge Escobar	
Transport	Light duty vehicle emission reduction	Edgar Fabris	Jorge Escobar	
Transport	Battery Electric Vehicles	Edgar Fabris	Jorge Escobar	
Transport	Hybrid Vehicles	Edgar Fabris	Jorge Escobar	
Household	Lighting switch residential	Fernando Canut	Int. B	
Forestry & Agriculture	Agronomy practices	Ximena Celis *(Ministry of Environment & Natural Resources)*	Int. A	
Forestry & Agriculture	Reduced Deforestation	Ximena Celis	Int. A	
Forestry & Agriculture	Grassland Management	Ximena Celis	Int. A	
Energy	Nuclear Energy	Fernando Canut	Antonio del Río *(UNAM)*	Edgar Rubí *(Ministry of Energy)*
Energy	Geothermal Energy	Fernando Canut	Antonio del Río	Edgar Rubí
Energy	Low-penetration wind	Fernando Canut	Antonio del Río	Edgar Rubí
Energy	Small Hydroelectric	Fernando Canut	Antonio del Río	Edgar Rubí
Household	Home solar PV	Fernando Canut	Int. B	
Energy	Coal CCS retrofit	Antonio del Río	Int. B	
Energy	Coal CCS new-built	Antonio del Río	Int. B	

Table 4: Abatement options cross-referenced with experts

4.3 Interview Results

Table 5: Interview results

	Cost & Financing			Multi-actor complexity			Physical Interdependences			Behavior		
Abatement Option	C1	C2	C3	M1	M2	M3	P1	P2	P3	B1	B2	B3
Nuclear Energy	2	2	2	(2), 1, 1, 2	1	1	2	0	(1), 2, 2, 2	(0), 1, 1, 1	2	(0), 0, 1, 2
Geothermal Energy	2	2	(2), 1, 2, 2	(2), 1, 2, 2	(2), 2, 2, 1	1	2	1	1	0	1	1
Low-penetration wind	2	(2), 1, 1, 1	1	2	(2), 2, 2, 1	1	(1), 1, 1, 2	1	1	0	1	(1), 0, 0, 0
Small Hydroelectric	2	2	(1), 2, 2, 2	2	2	1	2	1	0	0	(1), 1, 1, 2	2
Coal CCS retrofit	2	2	2	2	2	1	2	2	2	1	2	2
Coal CCS New-Build	2	2	2	2	2	1	2	(1), 0, 0	1	1	2	(2), 0, 0
Electricity from Landfill gas	2	1	(2), 2, 2, 1	(1), 2, 2, 1	1	1	1	0	0	0	1	(1), 0, 0, 0
Waste composting & recycling	1	1	1	2	1	(0), 1, 1, 1	(1), 2, 1, 1	1	0	0	0	(2), 1, 1, 2
Home Solar Photovoltaics	(2), 2, 1	1	1	(0), 1, 0	1	0	(2), 2, 1	0	(1), 1, 0	1	0	1
Lighting switch residential	1	0	(1), 1, 0	0	0	0	0	0	0	(1), 1, 0	0	0
Air transport	(1), 2, 2	0	0	(1), 1, 2	(0), 1, 1	0	0	0	1	(0), 0, 1	1	1
Modal Shift Freight Transport	(1), 2, 2	(0), 1, 2	(0), 0, 2	2	2	(1), 2, 1	(1), 2, 2	2	0	0	1	2
Transport Policy Changes	2	1	1	2	(1), 2, 2	1	(1), 2, 1	(1), 2, 1	0	0	1	2
Heavy duty vehicles emission reduction	2	1	(0), 1, 1	2	0	(0), 1, 0	0	(0), 0, 1	1	(0), 1, 1	1	(0), 0, 1
Light duty vehicle emission reduction	2	1	(0), 1, 1	2	(0), 1, 0	(0), 1, 1	0	0	1	(0), 1, 1	0	0
Battery Electric Vehicles	2	1	1	2	(0), 1, 0	1	1	0	1	(0), 1, 1	2	2
Hybrid Vehicles	2	1	(0), 1, 1	0	0	0	0	0	(0), 1, 0	(0), 1, 0	2	0
Agronomic practices	(0), 1, 1	(0), 0, 1	(0), 1, 1	0	1	0	0	(1), 1, 0	1	1	(0), 1, 0	1
Reduced Deforestation	1	1	(1), 2, 1	1	2	(1), 2, 2	0	0	0	1	0	(1), 1, 2
Grassland Management	(0), 1, 1	(0), 0, 1	(0), 1, 1	1	1	1	0	0	1	1	0	1

The results provided in this section were gathered using the preliminary Y-curve data from Chapter 3 and information from experts that was gathered from of interviews, an extended report of the interviews can be found in Appendix B. The numbers in brackets represent the preliminary scores given in Chapter 3 for easier identification of the changes made after the interviews.

4.4 Validation Process

After successfully completing the interviews with the experts the next step is to validate the results for the construction of the Y-curve. This section provides the requirements that were used to validate the results and an in-depth description of why the factors had a score change is provided to provide clarity on the scores that were assigned. To avoid conflicts between experts' opinions and the preliminary Y-curve developed a set of rules has been constructed to aid in this process and reduce misinterpretation or biased opinions towards a certain score. Every expert opinion for the scores that were changed in their respective interviews was considered and the arguments made for selecting any given score. The set of rules are as follows:

- Final scored is confirmed if the preliminary score does not suffer any change by the experts.
- If all the experts agree on the same score, which is different from the preliminary score, the score form the experts is considered as validated.
- If the preliminary score is validated by 1 out of 2 experts or by 2 out 3 experts the score will be validated unless a clear argument for changing has been presented in the interviews.
- If the preliminary score and the expert opinion are all different the tiebreaker will be the initial argument used for the selection of the score. The argument that most accurately reflects the reality of the situation of the country at the researchers' consideration will be selected as valid.

The arguments that the experts provide should be based on facts about Mexico and should reflect the current situation of the country. If an argument is outdated or does not reflect current governments agenda the argument will be considered "under advice" and will be reviewed if there is a difference in opinion from the other experts' opinion for the same abatement option.

Before presenting the detail description of how each score was validated and the reasonings behind it the "Validated Y-score table" (*Table 6*) is provided. If the number is not highlighted it means that the number was validated from the preliminary scoring and all the experts agreed on the grade given. If a number is highlighted it means that the preliminary score was validated but there was a difference in opinion from the expert interviews. Last, if a number is highlighted and shows two numbers with an arrow between them it means that the first number was changed to the "new" score after revising the experts' interviews.

Abatement Option	C1	C2	C3	M1	M2	M3	P1	P2	P3	B1	B2	B3
Coal CCS retrofit	2	2	2	2	2	1	2	2	2	1	2	2
Modal Shift Freight Transport	1-->2	0-->2	0-->2	2	2	1-->2	1-->2	2	0	0	1	2
Nuclear Energy	2	2	2	2-->1	1	1	2	0	1-->2	0-->1	2	0-->1
Geothermal Energy	2	2	2	2	2	1	2	1	1	0	1	1
Small Hydroelectric	2	2	1-->2	2	2	1	2	1	0	0	1	2
Coal CCS New-Built	2	2	2	2	2	1	2	2-->0	1	1	2	2-->0
Battery Electric Vehicles	2	1	1	2	0-->1	1	1	0	1	0-->1	2	2
Transport Policy Changes	2	1	1	2	1-->2	1	1	1	0	0	1	2
Low-penetration wind	2	2-->1	1	2	2	1	1	1	1	0	1	1-->0
Reduced Deforestation	1	1	1-->2	1	2	1-->2	0	0	0	1	0	1-->2
Electricity from Landfill gas	2	1	2	1-->2	1	1	1	0	0	0	1	1-->0
Waste composting & recycling	1	1	1	2	1	0-->1	1	1	0	0	0	2-->1
Home Solar Photovoltaics	2	1	1	0	1	0	2	0	1	1	0	1
Heavy duty vehicles emission reduction	2	1	0-->1	2	0	0-->1	0	0	1	0-->1	1	0
Air transport	1-->2	0	0	1-->2	0-->1	0	0	0	1	0-->1	1	1
Light duty vehicle emission reduction	2	1	0-->1	2	0	0-->1	0	0	1	0-->1	0	0
Grassland Management	0-->1	0-->1	0-->1	1	1	1	0	0	1	1	0	1
Hybrid Vehicles	2	1	0-->1	0	0	0	0	0	0-->1	0	2	0
Agronomic practices	0-->1	0-->1	0-->1	0	1	0	0	1-->0	1	1	0	1
Lighting switch residential	1	0	1	0	0	0	0	0	0	1-->0	0	0

Table 6: Validated Y-score table

4.4.1 Energy

Coal CCS Retrofit → the abatement option was discussed and review by 3 different experts and after looking at the numbers from the preliminary Y-curve they all agree with the grades that were proposed. They specified that from all the options this was the less likely to be pursued by the government considering the amount of money that had to be invested and the potential uncertainty on how much decreasing of GHG emissions would be led to. The experts also pointed out the little benefit of going after this option and that the money should be better allocated in other options with more upside.

Coal CCS Newbuilt → The validation of the scoring for this option was straightforward, most of the experts agreed on the initial scores with the main exception of two factors: "Disturbs regular operations" and "requires change in behavior". The main reasoning for downgrading the initial scores was that since the plant will be new built there will not be any change whatsoever in the day to day activities of the people on-site and thus also not requiring any change in their current behavior. These scores were validated because all the experts agreed on this reasoning when doing the interviews and giving similar arguments for the scoring.

Nuclear Energy → For this option the final Y-score presented is 17. The key factors that led to this high score were related to the cost and financing cluster, those number remained the same from the preliminary Y-curve, thus making the experts agreed with the initial valuation. For the multi-actor complexity factors, the main discrepancies were with the "dependence on other actors" were two out of three experts rated this factor with a 1, arguing that even though dealing with energy always depends on other factors the actor who has the final say is the government and if the government really wants to push for a new nuclear plant there should be able to do it. Considering the consequences of what a construction of a new power plant leads to, experts also argue that there should be a "change in behavior" in the community and how they approach their day-to-day lives especially with safety measures if they live near the hypothetical power plant. Other factors that were change were "Technology uncertainty" and "absence of knowledge of actor" the reasoning of the experts for this change was to emphasize the disasters that had occurred in other places and the concerns of safety had been raised, thus the increase in those factors to a score of 1.

Geothermal Energy → After three interviews with the experts, the scoring for the geothermal energy remained the same as it was during the preliminary Y-curve presented in Chapter 3. The factors were the interviewees were the result were uncertain because of the difference in grading were "difficulty in financing investment", "dependence on other actors", and "diversity of actors involved". The reason for the difference in grading for difficulty in financing investment was because one of the experts argued that the potential of geothermal energy should be enough to secure a loan to start a project capable of capturing this energy, while the others argued that the money is mainly going to the wind farms thus making geothermal kind of an unknown result leading for the preliminary score of 2 that was set initially to be validated. Meanwhile the dependence on other actors was argued that

the investors need to comply with government regulations and with general public for them to set a plant capable of gathering this energy, as well as, infrastructure capable to transporting it; on the other hand one of the experts argued that there are different small projects on geothermal energy running and more planned diminishing the role of the dependency on other actors. After careful consideration the score of 2 for the dependence on other actors was validated on the reasoning that the actors involved could be able to disrupt any potential geothermal energy project.

Small Hydroelectric → The total score for this abatement option was of 17. The validation of the scores was straightforward with all the interviewees agreeing with the majority of the scores with the exception on the score of one factor. The factor is "difficulty in financing investment", according to our experts this is due because Mexico does not have the water resources with the characteristics to host several projects of hydroelectric, the options available to build are few in the country and thus securing a loan without the incentive of the government is not easy to achieve. They also pointed out that building this type of plants is not a priority for the mexican government with investment going to other types of renewable energy. Another score that experts graded differently was related to the frequency of opportunity with some of them grading it as a one and one of them grading is as 2 because of the limited options on where to place the plant. The decision to score that factor as a one took place considering that two out of 3 experts selected that score and that even though the argument for a two was valid the initial scoring of one was validated.

Low penetration wind → Our expert interviewees agreed that most of the investment allocation was going to this type of renewable energy, mainly in the form of private companies' investment in specific geographical areas of the country with Iberdrola leading the way. Among all the energy options this was the best option to be pursued with an overall grading of 13. There were some changes in the grading compared to the preliminary scores and some scores that ultimately stayed the same, even though at least one expert had a different scoring number; all these factors are highlighted. Among the changes from the preliminary scores was "expected pay-back time" with experts agreeing that if done correctly the pay-back time should be between 5-12 years thus validating the score of one for this factor. Another factor that was decreased after the interviews was the "require change in behavior" with the experts arguing that the wind turbines does not affect day-to-day activities and a change of behavior is not needed. Factors that were uncertain among the experts were "physical embeddedness" and "division of roles and responsibilities unclear" with the latter been argued that electricity transportation is not fully develop and the communities over which the wind turbines are been built does not know their role while the physical embeddedness was also argued to cause a great change if the area where the wind farms were built was a common route for migratory birds or other species. In the end, all these arguments were considered and the validated score of both of those options remained as one.

4.4.2 Household

Lighting switch residential → After the interviews with experts the scoring remained mostly the same. The overall score was of two, decreasing one point compared to the preliminary grading. It was agreed by the experts that the initial score of one for "absence of knowledge of actor" should be change to zero. The main reasoning was that even though not all people know everything about the led lights they are aware that it will bring a benefit to their household becoming informed in their purchasing decision. The score of "difficulty in financing investment" had different opinions for our experts, some argue that the cost could be really high in comparison with their income and proposed a grade of 2 for that option, the final decision was set as one given the GDP per capita of the country is not high therefore making the change to be an effort for those households that ultimately decide to do it; the score of one is validated.

Home Solar Photovoltaics → For this abatement option the final validated scores were the same as in the preliminary Y-curve provided in Chapter 3. There were a few differences in opinion from the experts, those scores are being highlighted for better identification. For the "dependence on other actors" option one of the interviewees argued that most of the materials currently used for the panels are imported, mainly from Asia, and argued that the score should become a one. The reasoning for it to stayed at zero was that even though, the reasoning is good there is still a lot of different manufacturers that could compensate if any change with their main suppliers appears. The score for "initial cost required" was validated with a two because the actor deciding to install the solar PVs is the consumer and relative to income is a big investment for the household. The "physical embeddedness" factor also was validated with a two because the landscape of the house changes considerably and it makes physical changes that cannot be ignored.

4.4.3 Waste

Waste composting & recycling → For this abatement option two interviews with experts were realized. The grading was consistent through a lot of the factors and remained from the original assessment provided in Chapter 3. Nevertheless, there was a change in the scoring in two factors: "division of roles and responsibilities unclear" and "requires a change in behavior". The latter was first scored as a two, but the experts downgraded the scoring to a one behind the line of reasoning that the government has made a lot of efforts to separate trash into organic and inorganic and another step forward in recycling should not be hard to achieve, thus the score of one is validated. Meanwhile, the other factor that suffer changes was M3 because there are still a lot of structure issues for the way that the trash is being handle specially outside of big cities were dumpsters are part of different states making the change to one was the way to accurately score this potential issue when dealing with this factor.

Electricity from landfill gas → The factor that caused difference of opinions in this option was the "difficulty in financing investment" one expert argued that high initial cost and lack of proven return of investment was enough for putting investors off for lending money, while the other argued that in big cities the landfills are already there and getting something out of there that is beneficial for the community could be enough for grading this as a one. The score selected for this was a one because there are current talks of trying to pursue a model where the landfills are used to produce electricity outside the big cities. A couple of factors that also suffer changes were the "require change in behavior" expert argued that the landfills already exist and there are not many communities near them so it should be a seamless transition and not require any added effort in changing the behavior, the other is the factor regarding "dependence on other actors" because the landfills belong to municipalities outside of the city and could have different rules on how to handle content of the landfills and what is allowed to do with them, this score is changed to a two since the potential actor leading this option should be dependent on other state frameworks to make it work.

4.4.4 Transport

Modal Shift Freight Transport → This option suffered the most changes from the preliminary Y-score to the validated scores. This was because the experts pointed out the necessity of adding infrastructure into the conditions of the option for it to be feasible. The country lacks railroad and port infrastructure making it high investments. This leads to the increase in the scores for the "cost & financing" cluster to a number two in each case. In addition, this also leads to the "physical embeddedness" to be changed to a two. Also, the "division of roles and responsibilities unclear" was increased to status "unclear" given the many actors that are involved.

Transport Policy Changes → The main change in this abatement option occurred in the multi-actor complexity cluster in the factor "diversity of actors involved including conflicts". Experts argued the that the preliminary score of one was not enough to fully grasp the situation that changing the transport policy would mean. They argue that this option has the target to be implemented in the big metropolis of the country and could lead to unforeseen events from different actors representing different sector, so the score was validated as a two meaning that the diversity of actors can be considered as large.

Hybrid Vehicles → This abatement option had the best overall score from the transport sector with a grade of 7 positioning itself among the potential "quick-wins" that Mexico can pursue. The two experts that graded this option agreed on changing the "difficulty in financing investment" from a zero to a one, this is because the government has pushed for consumers to buy hybrid vehicles, but the benefits have not been economical there are no subsidies in place to soften the financial burden of the buyer. The other factor that was changed was the "technology uncertainty", experts' argument were based on the reasoning that hybrid vehicles are relatively new compare to fossil-based and

therefore overall efficiency should be improve over the coming year to make them more attractive for the general public to purchase them.

Battery Electric Vehicles → For this option the experts agreed in the grading of most of the factors that was provided to them from the preliminary Y-curve. However, they decided to change factor "diversity of actors involved including conflicts" from a zero to a one basing the decision that these vehicles need charging stations to fully operate leading to include energy generation providers and government to also be involved in the planning of any development in the Battery electric vehicles network. Another change was in the "absence of knowledge of actor" factor because the range of the battery from this type of vehicles should be improved and there is a lot of room for improvement in the logistics of where to have charging stations, and the time that it requires for your car to have a full-charge; all this factors change the perception that the actor does not have all the answer and the score of one is validated.

Light-duty vehicle emission reduction → This abatement option had an overall score of 9 meaning that according to the Y-factor method this option is a good alternative to be pursued. The experts change the "difficulty in financing investment" to 'medium' given that the money will have to be spent on research and there is no guarantee of finding solutions in the short term, the factor is not graded as high because there is still a lot of consumers for the market and a lot of the vehicle are also exported to countries like the USA or Canada. "Division or roles and responsibilities unclear" is graded as slightly because there is not a focus on which area of the car need to be improved it could be the engine or the car design to consume fuel more efficiently or it could be that the fuel that is been used needs to be altered in some way. This explanation also goes in-line with the factor "absence of knowledge" because the automotive industry is in constant innovation and experts' argued that anything involving a different kind of fuel is hard to measure long-term consequences hence the score of 1 for the factor.

Heavy-duty vehicle emission reduction → There were several changes across the board for this option. "Difficulty in financing investment" was increased to a one because even though it is a highly profitable industry in Mexico were a lot of heavy-duty vehicles are been transported to the US they still need to invest in R&D to be able to comply with the norms and international regulations making it not as straightforward to find external investment. The "technology uncertainty" factor was also increased to a one considering that the research needs to be for the emission reduction, and this could be done by different measures like improving engine efficiency and fuel consumption or by developing a new bio-fuel, these options led to the uncertainty and the score been validated.

Air Transport → This option was related to the potential changes in the fuel used in the aviation industry. The experts rated the "investment cost required" as large given the amount of money that need to be allocated to research and development to have success in this type of project. Experts also express that "dependence on other actors" was a lot given that probably the person that comes up with a solution to this problem will be working in another setting, they gave examples that breakthrough could arrive from university labs rather than from within the industry, this also increases

the factor “diversity of actors involved” to not just the air transport industry but rather a whole network of people working with fossil-fuels and bio-fuels, thus increasing also the score of that factor. Meanwhile the “absence of knowledge of actor” was also increased to a one, the explanation provided was that it will be a new fuel and it will need time to be commercially applied to the industry and when it arrived the knowledge of the “new” fuel will be limited for the industry.

4.4.5 Forestry & Agriculture

Agronomic Practices → The experts agreed that the scores of zero given in the preliminary assessment for the cost & financing factors were too low for the current situation in Mexico. The main argument behind changing these scores was because the farmers in Mexico only own small plots of land leading to low yield returns and therefore any money used to improve its practices will not have the desired effect in a small land. The interviewees decided to change the scores to a one in all the cluster to accurately portrayed the current situation validating the results in the process. Another factor that also changed the initial scoring was the “disturbs regular operation”

Grassland Management → All of the changes for this abatement option occurred on the cost & financing factors with each of them being scored as a one instead of a zero. The reason for this was that from the owners’ point of view the investment on learning how to manage the grassland are costly and lead to not being able to find potential ways of financing through bank loans. This issues also lead to a low return of investment with higher payback time than expected.

Reduced Deforestation → This abatement option had three grades that were changed after the interviews were made. “Require change in behavior” was listed as severe by the experts considering the actual rate of deforestation and the low replenishing rate of it. “Difficulty in financing investment” was also upgraded to a two since it is hard to find money for preventing on using resources, the actual programs allocated little money to the preservation of the forest and is viewed as not a smart business for investors. The last factor to suffer changes was “division of roles and responsibilities unclear” experts’ opinion on this factor were related to the size of the forest that it involved a lot of land and the communities that live near those lands usually take care of the forest but that is an unwritten rule rather than the law, what has happened is that easily accessible forest are exposed to illegal cutting of trees and nobody is held responsible for those actions because there is no responsibility of who should be in charge of the protected areas, validation the “unclear” grade given.

4.5 Validated Y-curve

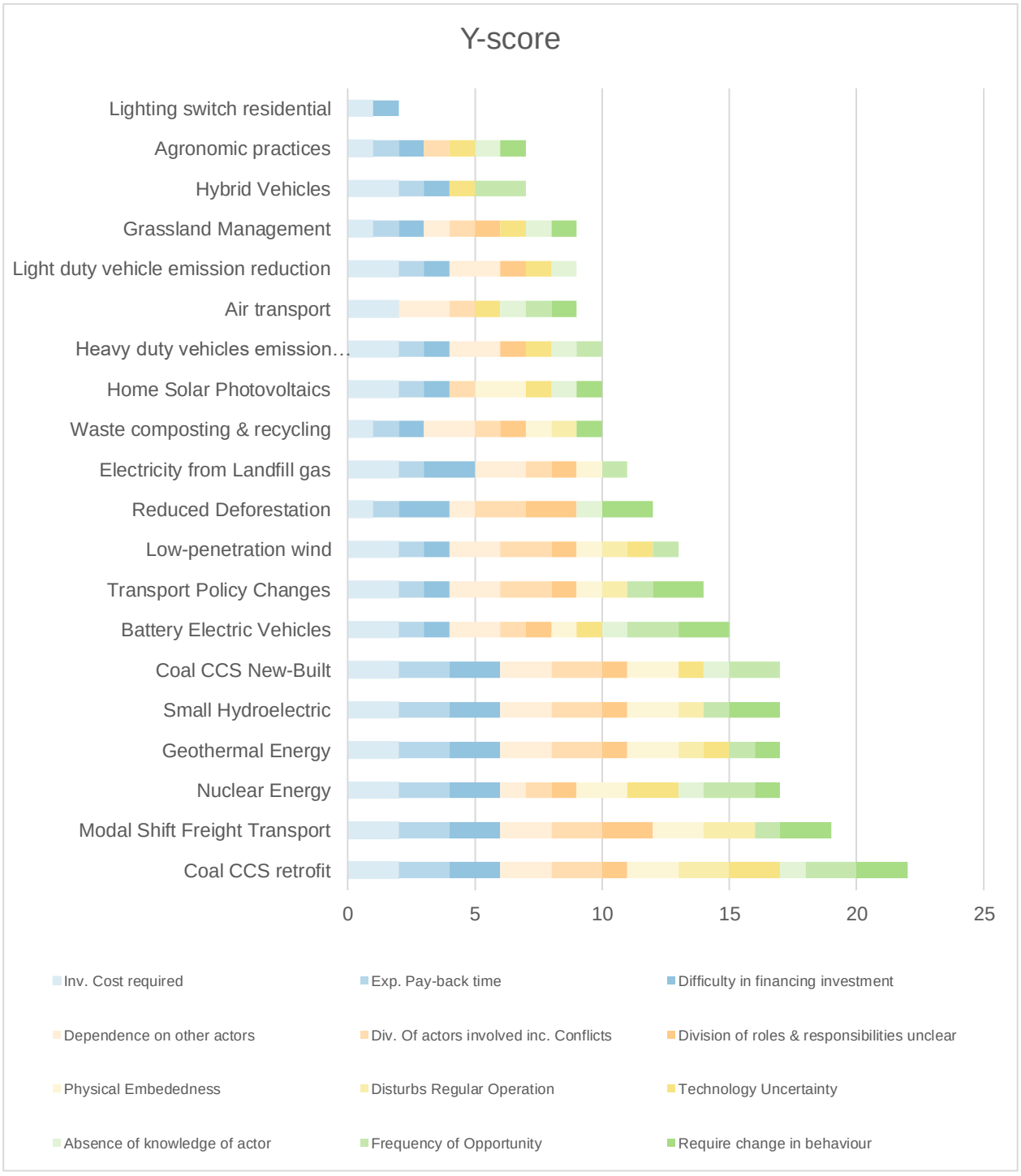

Figure 20: Validated Y-score by factor

Figure 10 is the result of the validated values of the factors for each abatement option. Each cluster of factors is been color coded for easier recognition, as well as, picturing the whole value in the same chart.

4.6 Chapter 4 Conclusions

This chapter revolved around what new information could be gathered and synthetized to further improve the accuracy of the scores for the abatement options. The main objective which was to

answer the sub-question *"How can expert interviews improve the understanding of the barriers that hamper the emission abatement options through the Y-factor method?".* The utilization of experts to help in this research serve two main purposes; the first, to decrease subjectivity by having at least two experts score the same abatement option, and the second, to add new knowledge and improved accuracy to better depict reality in Mexico. The results gathered are considered a validation of the work done from Chapter 2 and 3 because more than half of the scoring remain unchanged from the preliminary assessment, it also helped by improving the accuracy by changing some scores because of personal knowledge and experience from the experts that could not be find in literature review. This chapter also helped by understanding more about the Y-factor method and how people who are not familiar with it react and search for the usefulness of it. Several experts made some remarks about possible improvements, but they mostly agreed that recognition patterns gathered through the method are useful for understanding why some abatement options are not pursued. In conclusion, involving experts helps with the investigation through opinion that further validate or improve how the factors of the abatement options were scored and also aided in added feedback on how to refine the Y-factor method according to them.

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SECTION 5
Results Analysis

CONTENT

5. Results Analysis

5.1 Comparison preliminary Y-curve & validated Y-curve

5.2 Comparison between Ranking MAC and Ranking Y-curve

5.3 Y-factor meaning in Mexico's current affairs

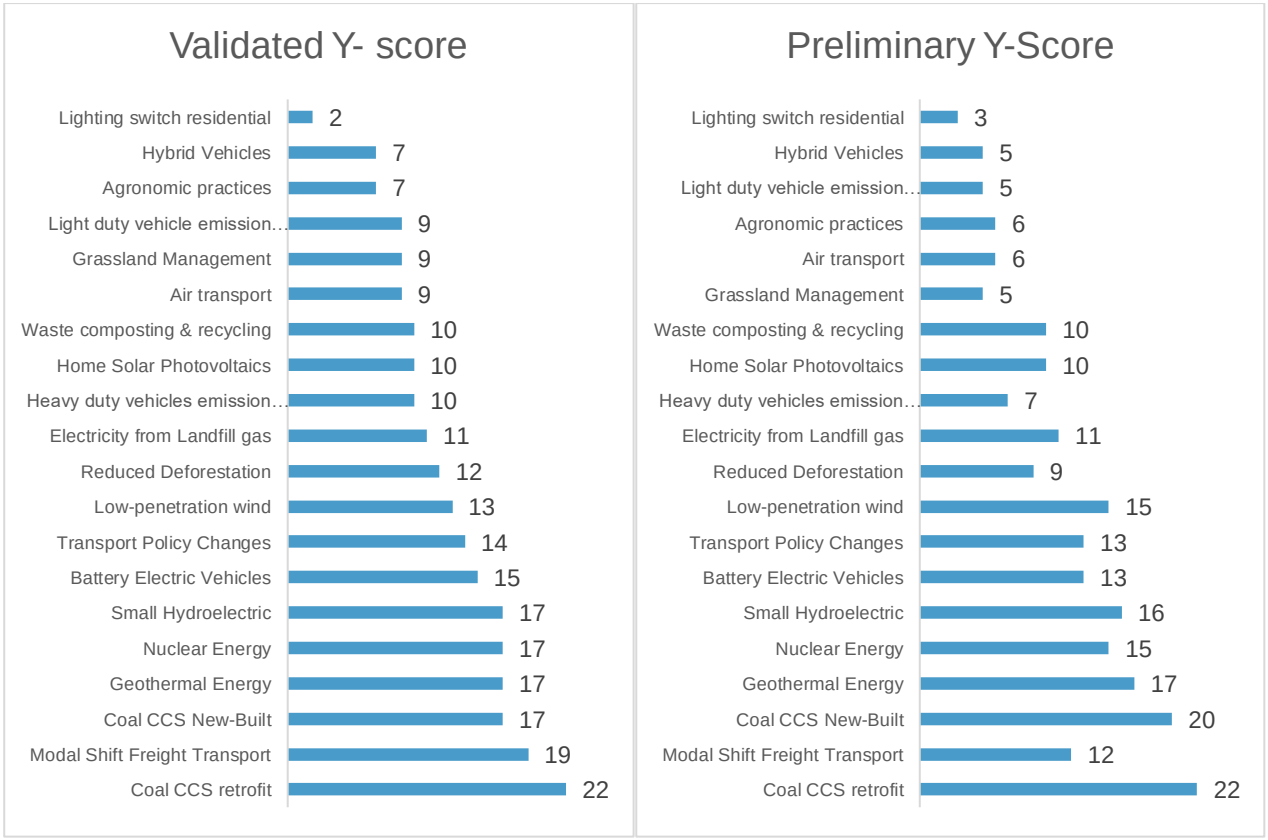
5.4 Chapter 5 conclusions

05.

5. Results Analysis

This chapter aims to synthetize the analysis of the results gathered from previous chapters and the interpretation of the findings from those results.

5.1 Comparison preliminary Y-curve & validated Y-curve



At first glance, the data provides portrays that the validated curve has their abatement options scoring higher than in the preliminary chart. If a sum of all the scores is performed the discrepancy in the number is highlighted even more with a 247 total sum for the validated graph compared to 220 for the prelimnary. This means that the experts opinion increase the difficulty in realizing almost every abatement option, this also showcases the difficulty on scoring accurately socio-technical factors that cannot be measure with numbers but that contribute to the lack of action in pursuing the abatement options.

Analysing more deeply the abatement options it was found that in general the most difficult options to pursue are the options related to energy. This is in line with common knowledge of why it takes a lot of time in planification to start doing this massive projects. An option that was rated to low in the preliminary Y-curve was the modal shift in freight transport, the premise of the preliminary rated was based on the perception that the changes will be made just from a logistics standpoint and scheduling management but the expert interviews displayed that this is impossible considering current infrastructure specially in train railways and port infrastructure. This made it the second most difficult abatement option to pursue.

On the other side of the spectrum the “obvious” abatement options to tackle and look at ‘quick wins’ are lighting switch & hybrid vehicles which all the cost goes to the private person, this is a bit an issue because considering the state of the economy in the country not every household is capable of investing in a new car and some and expenses to change lighting are mostly inconsiderate. Another option is to tackle the forestry sector with the main obstacle being that small farm property is the economic model in the country leading to have to deal with a big number of persons for limited results.

5.2 Comparison between Ranking MAC and Ranking Y-curve

Abatement Option	Ranking MAC	Ranking Y-score
Transport Policy Changes	1	13
Lighting switch residential	2	1
Hybrid Vehicles	3	2
Light duty vehicle emission reduction	4	5
Air transport	5	4
Geothermal Energy	6	16
Heavy duty vehicles emission reduction	7	9
Home Solar Photovoltaics	8	8
Electricity from Landfill gas	9	10
Battery Electric Vehicles	10	14
Agronomic practices	11	3
Waste composting & recycling	12	7
Small Hydroelectric	13	17
Low-penetration wind	14	12
Grassland Management	15	6
Reduced Deforestation	16	11
Nuclear Energy	17	15
Coal CCS New-Built	18	18
Coal CCS retrofit	19	20
Modal Shift Freight Transport	20	19

A comparison between the abatement cost ranking and the Y-score ranking of options leads to understanding the complexity of why some of this abatement options are not pursued. Transport policy changes figures as the easiest choice to consider if data from the MAC ranking is used, in financial terms it looks like a solid option to consider but other factors involving different actors make it not as straightforward to implement. The Y-score ranking leaves this option at number 13 meaning that there are at least half more convenient options to look at that.

If we look at the energy cluster almost all the abatement options rank in the bottom of both rankings meaning that challenges in doing these options are not only from a financial perspective but also involves multiactor, and behavior complexity, as well as important changes in the physical landscape. An exception is the Geothermal energy, this option has a discrepancy of 10 places if we compare both rankings meaning that the abatement cost potential is solid considering the characteristics of the country but the all-around complexity exposed from the Y-factor forces to develop an action plan that takes into account more than just the financial aspects for it to be feasible.

In contrast, factors like ‘waste composting & recycling’, ‘agronomic practices’, or ‘grassland management’ do an inverse jump from the rankings. They are measured as being in the bottom half in terms of feasibility from

the MAC ranking but the Y-factors places them as viable candidates to be pursued. What this comparison shows is that looking at just one ranking can be deceiving. If only the MAC ranking is considered, there are hidden factors that could hamper the implementation of the abatement options, the MAC helps you look in abatement costs terms but misses on other important factors such as conflicts between actors or even potential changes in day to day activities. In contrast looking at the Y-factor ranking provides a score that already considered other factors beside the financial perspective giving it a more complete outlook of the situation. It is important to notice for policy makers that looking at the overall Y-score gives the score of how the abatement option fared against all the factors but for a more comprehensive outlook the view of a disaggregated graph can help portray the situation better.

5.3 Y-factor meaning in Mexico's current affairs

This section has the purpose of informing which is the feasibility of Mexico leaning to pursue the abatement options selected. An explanation of Mexico's current affairs is also portrayed to see the current state of the country and the priorities that the government is targeting. It must be noted that Mexico is in a transition since a new government administration arrived at the end of 2018 leading to some changes from previous expectations.

The Mexican federal government along with the states and municipalities are the ones responsible for developing their own climate change programs and develop a roadmap for the results of reducing the GHG emissions of the country. "The General Law of Climate Change gives state governments climate change mitigation and adaptation responsibilities in transportation and infrastructure, land use planning and urban development (in coordination with municipalities), and special management wastes. 51 Municipalities have jurisdiction over water supply and sanitation, local land use planning and urban development, natural resource management, municipal solid waste management, and public transportation" Rebolledo et al (2016). Thus, subnational governments influence most of the land use planning processes that affect GHG emissions. However, close coordination among federal, state, and municipal governments in Mexico is needed to achieve emissions reductions in transportation, urban planning, and municipal services requires.

5.3.1 Transport

The transport sector is one of the biggest GHG emissions contributors in the country, for this study a total of 7 abatement options related to this sector were selected and analyzed with emphasis on having representation along all modes of transport. Road transport continues to be the most high-profile contributor of the emissions inside this sector. Abatement options to decrease these emissions range from lowering light-duty & heavy-duty transport emissions, private vehicle owners switching towards hybrid or electric cars or adapt a transport policy to target reduction. According to

the Y-score the best option to be looked after is to buy hybrid cars, the government should embrace credits or benefits for people trying to change for a more environmental-friendly vehicle.
An option that seems to yield the highest benefits is regarding transport policy changes, the Y-score in this one features a great challenge in dealing with the different actors involved and the potential backlash from them. Nevertheless, current affairs appear to be unstable and future problems will continue to rise. Recommendations vary from using shared transportation initiatives involving school buses or even work buses to highly dense areas, improving public transport, or making a secure and protected bike lane for mobilization. The Y-factor helps in exposing the complexity of this abatement options and focus resources in were they need to be, optimizing emissions for light-duty and heavy-duty transport can be pushed by having state of the art engines and enforcing emission policies to manufacturers so that they invest in the necessary research and development. In general, the transport sector is key for Mexico to improve current emissions and policy-makers should be conscious to target abatement options that are feasible and that could lead to long-term benefits.

5.3.2 Energy

Mexico has always relied from international investment, mainly through grants or concessions, when it comes to investing in renewable energy. The largest public fund had an allocation of 18 million USD for renewable energy, and the Ministries have very little resources allocated to reducing GHG emissions. A starting point of making renewable energy investment attractive is important for the country to follow any potential abatement options available.
After analyzing the abatement options with their performance using the Y-factor method it was realized that the least attractive options that the government should follow were the construction of a coal plant or the retrofit of it. The score of Coal CCS Retrofit was the highest of all the abatement options at 22 points while Coal CCS New-Built had a score of 17 comparing this ranking with the abatement cost from the MAC it can also be inferred that there should not be a priority for the government. Nevertheless, the new administration that started at the end of last year has put on hold government investments in renewable energy and gave the green-light for a new coal plant construction. This will further derail the potential of reducing emissions and hamper the budget for other types of energy.
The best abatement option of energy based on their Y-score was ‘low-penetration wind’ energy. The highest investor in this type of energy is a foreign company called Iberdrola which has managed to develop a wind park in the state of Oaxaca. An energy option that goes under the radar is the geothermal energy, the capacity of the country leads to potential investment in this type of renewable energy. The interviewed experts were positive on the future of this type of energy specially in the center of the country were a volcano ring is present. The Y-score of this energy in on-par with other energy options making it worthwhile to make follow-up inspections and to potentially attract foreign investment.

The main barriers that can lead to problems when investing in clean energy technology in Mexico are the upfront costs (government cannot paid them and is dependent on foreign investment), a lack of regulatory framework (mainly weak rules and limited compliance with current laws), institutional awareness (lack of track record on successful clean energy investments, challenges to raise awareness on the role of energy efficiency), industries rely in energy subsidies (energy subsidies reduce the desire to invest in more efficient energy processes). These barriers and the changes in government direction lead to less desirability for foreign investors to put money on the country.

5.3.3 Household

The Mexican government rewards households with low electricity consumption by subsidizing a part of their bill. This leads to electricity payment in the household not being a problem at all; therefore, a lack of interest in installing cost effective solutions such as our abatement options 'solar PV panels' or 'changing their lighting'. Despite this there is a percentage of the population that pays more for their electricity, this is because in contrast of the government rewarding for low electricity usage your bill is higher because of all the electricity you use. This involves a little bit more than the 1% in Mexico which are the households that also possess the biggest houses and that are more environmental aware. The MAC and Y-score shows that changing the lighting in the household and using LED's in a great investment but not a lot of houses or companies are making the change. Government should target doing this change gradually, they could start by enforcing companies to only be allowed to buy LED's and start taking incandescent light bulbs out from the market.

Regarding the use of solar PV panels in households, the lack of space in installing those panels is a key on not being able to make the transition. There has been a growing trend were materials and PVC tubes have become more affordable leading to more people using the solar PV panels specially for their water heating instead of using gas, but it has not become a widespread technology in the country.

Household reduction of emissions is currently not being targeted by the government and it is an opportunity that could lead to good results in a short span of time. Government has focused on raising awareness, but the choice has been entirely up to the public, low electricity bills and lack of long-term planning in the population are drivers for these measures to be left behind compare to other more high-profile abatement options.

5.3.3 Forestry & Agriculture

The Y-score projects this sector as some of the more feasible abatement options to tackle and help reduce the GHG of the country. The options that were analyzed are "Agronomic Practices", "Reduced Deforestation", and "Grassland Management". All these options ranked in the bottom half of the Y-score ranking with values below the 10 points. A coordinated effort to pursue this abatement options should be pursue considering the long-term benefits for food production while investing in

agronomic practices and grassland management, while reduced deforestation would help preserving and cleaning the GHG and help long-term planning.

Mexico's territory for forestry and agriculture is divided as follows: 34% to forest and 15% to agriculture. The structure of land owners for agriculture in the country is one of the main barriers in pursuing the abatement options considered; most of the owners only have a small piece of land and therefore for many of them is not feasible to consider spending on smart crops techniques or investing in management courses for better yield production. To successfully pursue going after this abatement options the federal government should deliver low-interest loans for farmers to make this feasible. Current budget allocated for agriculture programs is not enough and is an issue with long-term problems in food production.

Regarding reduced deforestation the main issue is to protect trees from illegal cutters, about 8-9 million cubic meters of wood are cut illegally each year and are not properly replaced. Current programs involve paying local for forest conservation, even though this has work in some measure there is a lot of room for improvement. It is imperative that forests are kept and maintain to help with the GHG mitigation but a clear plan and framework for forest conservation should be implemented.

5.4 Chapter 5 Conclusions

As observed in the Outline, in this chapter the main question to answer was "*What are the implications of the Y-factor scores?".* This question was answered in different sections that revolve around different objectives. A comparison between the marginal abatement cost of McKenzie against the Y-factor ranking was meant to be as informative in understanding that there are more than financial barriers involved. The other aspect is how the results gathered were meant to impact in Mexico's current affairs and how the barriers could be dealt with in order to pursue the implementation of the barriers. A remainder of the process is that due to the timespan a limited number of abatement options had to be selected from the start and possible abatement options that are being currently pursued might have been left out giving a partially incomplete picture, and this can lead to alterations in the analysis of results if a higher number of options was investigated.

SECTION 6
Conclusions & Recommendations

CONTENT

6. Conclusions & Recommendations

6.1 Thesis recapitulation

6.2 Recommendations to reduce GHG in Mexico

6.3 Limitations of the study & suggestions for the Y-factor

6.4 Reflection

06.

6. Conclusions & Recommendations

This section is the last chapter of the master thesis. It reflects on the step-by-step process of the construction of the validated Y-curve from the selection of the abatement options for Mexico, the subsequent scoring and construction of the preliminary Y-curve, the validation process relying on expert interviews and analyzing the results provided. Then, the main limitations characterizing the performed research and a list of possible recommendations is proposed. The chapter concludes with a series of suggestions that were gathered when doing the interviews and from personal experience while doing this research.

6.1 Thesis recapitulation

This section is meant to synthetize the steps followed during the research and present the result of the most important steps of the work.

The goal of this master thesis research was to construct a reliable emission abatement curve using the Y-factor method in a specific case study (Mexico), able to provide new insights not only in financial barriers but also in the multi-actor, behavior and physical categories and realize which of this barriers was obstructing the implementation of the abatement options that were selected. The implementation barriers considered in this research are the ones proposed by Chappin (2016) in the Y-factor method. As a recapitulation of the development of the Y-factor method is the introduction made by Chappin (2016) which initially development the abatement curve by assigning scores for its construction, and Soana (2018), which was the first construction of an abatement curve using the aid of expert interviews to make the results reliable.

To follow the logic used by Soana, the Y-curve developed in this thesis has to reduce opinion subjectivity and showcase reliable scores. When dealing with the 12 socio-technical factors that the method presents it is hard to have quantitative date that fit each and every one of the factors involved. The scale of the grading utilized (0-2) is meant as a guideline to portray how “easy” or “difficult” is to implement the given abatement option; therefore, the scoring cannot be compared in the same way for the cost and financing category or the multi-actor perspective preventing the researcher for doing factor comparison inside the same abatement option. To validate the results, it was relied on the opinion of 8 different experts that gave their own opinions about the grading of the abatement options and where then put through a validation purpose that could help limit subjectivity and improve accuracy on the scoring of the options displayed in the Y-curve.

The main research question was the following:
What emission abatement curve can capture the complexity of reducing GHG emissions in Mexico?

The main conclusions achieved by this investigation are the following:

- The main purpose of creating an emission abatement curve was successful. The Y-curve involved 20 abatement options which were graded by different sector experts of the country. These were retrieved via 8 interviews were every single abatement option was reviewed by at least two experts. The validated Y-curve is significantly rich in arguments better portrays the reality of the country. Most of the preliminary scores were validated by the experts and their added knowledge in specific sectors further improved the accuracy of the Y-curve; only about 15% of the scores had different grading provided experts' opinions at the time of grading. The Y-curve is more robust over time than McKinsey's MAC curve, as it is not only dependent on the cost which can lead to vulnerability to market fluctuations, but rather considers a more well-rounded overview of the factor that could hamper the abatement option and thus the scores are prone to subjectivity it must be noted that the purpose is to uncover the complexities that are associated with the abatement options.

- The Y-factor and the obtained Y-curve were positively welcomed by the interviewees specially by the persons who, at the time, were working for the government Ministries of Transport, Environment, and Energy because they were often just looking at the financial issues of trying to implement certain abatement options. They accepted the method to understand why certain options are difficult to pursue and that this tool could help educate and showcase the whole ramifications of taking certain decisions. Some interviewees suggested that this tool be used to teach the general community about how to take decisions, while other was more interested in trying to expand the grading to more than just the 0-2 scale currently used. Everyone agreed that analyzing beyond the financial aspect should be a pre-requisite and that using the Y-factor could be a reliable way to do it.

- 3. Adding to the previous works on the Y-factor from Chappin (2016), Arensman (2018) and Cheung (2018), and Soana (2018) this investigation has added the implementation of the Y-factor into a third world country and made a reliable emission abatement curve for the country. This addition provides the platform to apply the Y-factor into specific countries or regions and analyze vulnerabilities and areas of opportunity for each new case-study; therefore, the investigation expands on the theoretical background of the Y-factor method for future applications.

6.1.1 Preliminary Y-curve

The following sub-research questions guided the creation of the preliminary emission abatement curve.

SQ1: What are the relevant abatement options needed to reduce GHG emission in Mexico?

Selection of the abatement options → The selection took place by developing a selection criterion based on a previous shortlist provided by Soana (2018) which, in itself, was a reduction from the McKinsey global curve and the 218 options initially selected, and been aided with the information provided by the marginal abatement cost developed by the US government for their low emission development program of Mexico. The result was a selection of 20 abatement options to study for the country: Electricity from Landfill gas, Waste composting & recycling, Air transport, Modal shift freight transport, Transport policy changes, Light-Duty vehicle emission reduction, Heavy-Duty vehicle emission reduction, Battery-Electric vehicles, Hybrid vehicles, Agronomic practices, Reduced deforestation, Grassland management, Nuclear energy, Geothermal energy, Small Hydroelectric, Low-penetration wind energy, Coal CCS retrofit, Coal CCS new-built, Home Solar PVs, Lighting switch from incandescent to LEDs.

Overview of the selected abatement options → The selected abatement options were further reviewed and information, when available, was gathered to highlight important data such as emissions, costs, definition of the option to avoid subjectivity, potential issues that could hamper its implementation, and information related to the abatement option in Mexico.

SQ2: How can the Y-factor method identify the barriers that are hampering the implementation of the selected emission abatement options?

Scoring of the abatement options → Based on the literature and information gathering the scores are displayed in chart form. The scoring is based on the Y-factor method by Chappin (2016); the scale used is from 0-2 with the bigger number resulting in a higher degree of difficulty to implement the given abatement option. The detailed explanation of the scores can be found on the Preliminary Y-curve chapter and explanation of the reasoning for giving the grades.

6.1.2 Validated Y-curve

For the validated Y-curve the sub-research question 2 was asked again to a group of experts in the form of interviews for validating the previous scoring. The validation had the purpose of making a reliable Y-curve that was not only based in the researchers' opinion, but rather an expansion and complementation of the work done in the Preliminary Y-curve section with the aid of experts' opinions regarding the scoring of the different abatement options.

SQ3: How can expert interviews improve the understanding of the barriers that hamper the emission abatement options through the Y-factor method?

To successfully answer this question using experts' opinions an interview template was created. Then communication between the researchers and the experts was made via email, LinkedIn, and government websites to ensure participation in the validation process. These interviews were used

to validate the preliminary Y-curve scores which would result in a validated Y-curve chart through validation process when different points of view by the experts resulted in a different scoring.

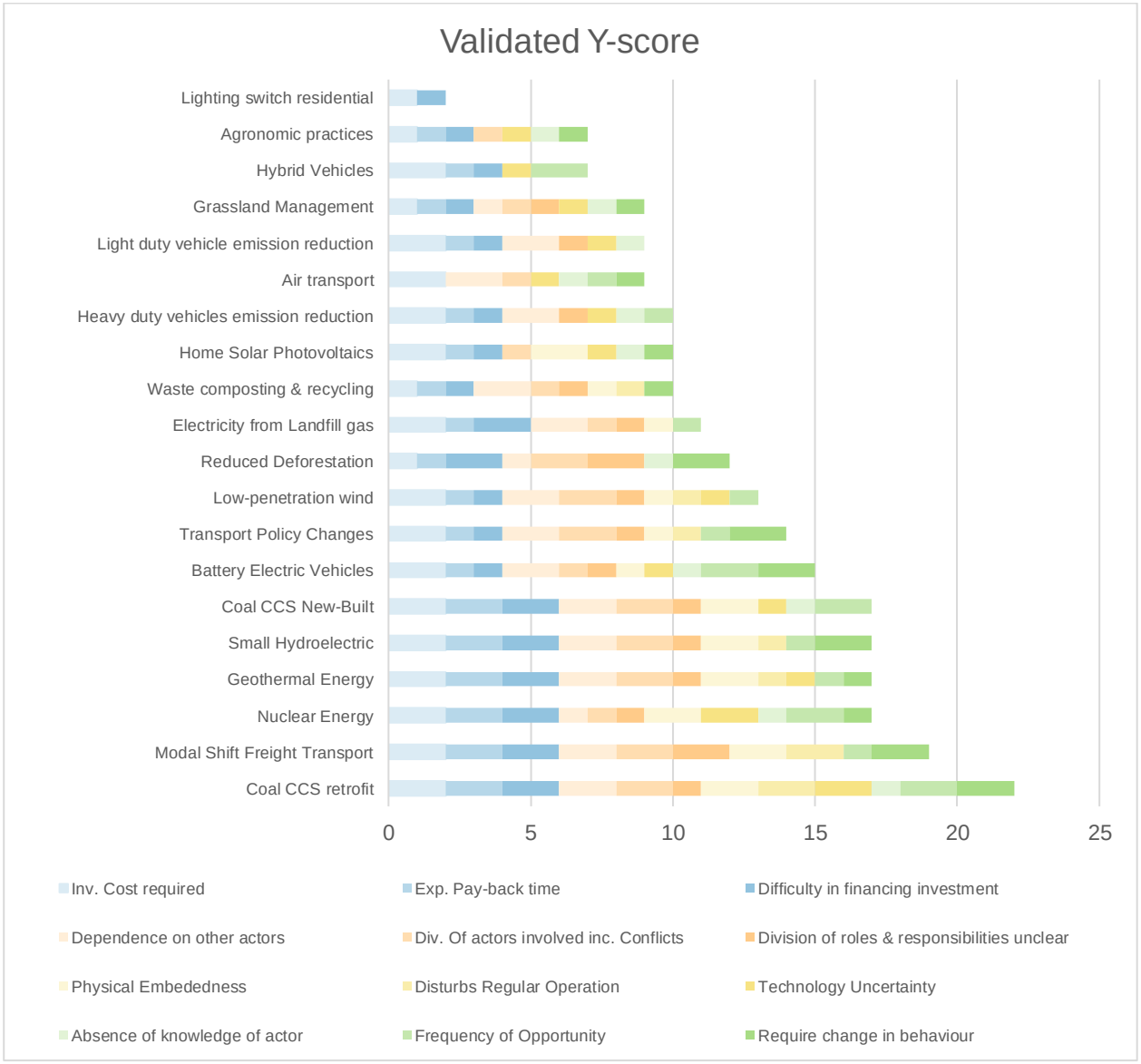


Figure 30: Validated Y-score by factor

The results of the validated Y-curve were the construction of a reliable emission abatement curve that represented the reality of the current situation in the country. That goal was fulfilled by reducing the subjectivity of the opinions by increasing the sample size of the number of experts capable of grading the abatement options. The results also gave us a better explanation on how to better plan to pursue the abatement options and the potential pitfalls of them.

After analyzing the results and gathering the most valuable insights a series of recommendation were prepared to help aid in the process of reducing the GHG emissions of Mexico in the goals of 2030 and 2050. The recommendation can be found in the following section.

6.1.3 Main conclusions by chapter

Chapter 2: In this chapter the most relevant process of the thesis was performed. The selection of the abatement options was the foundation for the whole research report. It is important to note that it is difficult to narrow the number of abatement options to fit into the timespan of the project and that the chosen options are meant to represent the reality of current affairs in the country with special interest in specific clusters such as transport and energy to investigate.
Chapter 3: This chapter was the culmination of the preliminary Y-curve. The purpose was to be use the available information through literature review that could portray Mexico's reality on how they are pursuing the abatement options selected and which barriers are slowing or obstructing their implementation. Results in this chapter are informative because sometime not every aspect of the abatement options can be found, and this part was meant to be as the initiation of discussion with experts that occurred in chapter 4.
Chapter 4: The conclusion of this chapter is the validation of the investigation done for constructing an accurate chart of scores of how much each factor affected the abatement options selected. This is also considered the ending of the research and the Y-curve constructed was validated through by the different abatement options. As a added insight, some experts also gave their opinions on how to improve the Y-factor method.
Chapter 5: In this chapter the conclusion is about the implication of the results of the Y-factor. I concluded that it is a more robust approach than the MAC method because it involves more than just the financial barriers and also it is a method that help identified the soft sport of the abatement options, leading to understand which barriers hamper any given abatement option implementation.

6.2 Recommendations to reduce GHG in Mexico

This section has the purpose on advising on possible recommendations that were based on issues raised by the experts during the interviews and the insights gained through doing this research with the aid of the Y-factor.

- There is a gap between planning and implementation. In Mexico there are a lot of municipalities that have developed climate change programs, but many of the actions needed to reduce the GHG emissions are not been pursued. According to Jorge Escobar, this is mainly due to lack of financial support, absence of technical skills, and an absence of knowledge of understanding the complexities of implementing the given abatement options. The Y-factor portrays a simple, yet efficient way to uncover some of these complexities and it is useful to apply it to the abatement options that the federal and state governments have identified as key in reducing the emissions. This will improve general understanding and hopefully speed the clearance process to pursue the options that have been highlighted by the climate change programs of the municipalities.

- The process, including every step, of developing an emission abatement curve could be used as a stepping stone into a more concrete simulation. Mexico needs the modeling capabilities to support the current energy transition and optimize resources currently available. The utilization of the steps performed in this thesis, namely: selecting abatement options, scoring them through research, and validating them is a good starting point to understand the situation and provide a platform for future dynamic modeling involvement.
- An issue that was raised during the interviews was the lack of a clear framework for climate change programs. Each municipality has some sort of environmental program, but they could be structured in several ways, this leads to confusion and lack of replicability since there is no structure on how they are performed. The design and evaluation of this framework needs to be strengthened and this will help improve clarity and understanding of how to complete the goal of reducing current GHG emissions.

6.3 Limitations of the study & suggestions for the Y-factor

This section has the purpose to expand on the limitations on the thesis and the suggestions for improving the Y-factor method based on the results obtained and the opinions gathered from the experts contacted.

6.3.1 Limitations

- Due to time-constraints the pool of abatement option had to be limited to 20 options. In an ideal scenario these options should be expanded and ranked accordingly to see the most fitting ones to follow for the country.
- The validation of the Y-curve was based on the interviews of the experts. The interviews are subjective to a person's opinion and view of the current situation. The study tried to reduce this subjectivity by inviting several experts to validate the scoring, but the limitation is that 2 or 3 persons validating the score is a small sample and this number should be increased to have a more accurate number reducing even more the subjectivity of personal opinions.
- The interviews that were performed in this study had the constraint of been limited to the experts' availability which often translates in having interviews of 1 hour or less. This makes it hard to have each expert score each socio-technical factor of every abatement option one by one and thus a simplified method were the preliminary scores were initially provided could cause biased in the results. The more accurate option is that the interviewee grades on its own each of the scores of the factors.
- Most of the interviews had to be performed remotely resulting in some sort of lost time and hurrying through some of the options. An ideal scenario will involve face-to-face interviews with useful discussion to avoid unintended distractions.

6.3.2 Suggestions to improve the Y-factor

- It was suggested to expand the scoring range from 0-2 to a scale from 0-5. This with the purpose to continue with the simplicity of the method but improve the accuracy to score and better reflect reality.
- Experts often discussed adding different factors to improve the method. Some of the factors that were discussed as possible additions were “government approval”, “short-term abatement potential”, and “long-term abatement potential”. These options were not further discussed with the experts, but they felt that there was some sort of factors for attractiveness that were missing from the current pool of socio-technical factors.
- The validation of the Y-curve through expert interviews is a time-consuming approach that is somewhat repetitive when doing for a high number of interviews. I suggest, if possible, to have a discussion panel where discussion between experts is more fluent and the scoring of the abatement options will be more accurate. Ideally, this panel would have experts knowledgeable with the abatement options with different background so they can complement each other and have more insights when discussing the grading.

6.4 Reflection

After a 5-month period of doing research, studying about how Mexico deals with GHG emissions and gathering valuable information through experts’ interviews from around different sectors. The following section has been designed to reflect on the scope of the research from different angles: societal, and academic. The views written in the reflection are from my personal point of view.

6.4.1 Societal Reflection

How to reduce GHG emissions has become a recurring topic in the Mexican government in recent years, the country has pledge to make changes and see results in the upcoming years. Nevertheless, there seems to be hesitation to start doing changes in the country, this has led to local environment organizations to criticize the government and advocate to change current policies. After speaking to a wide range of experts and discussing the Y-factor method there was some expectation on what this line of thinking could mean to taking decisions. The Y-factor method aims to provide insightful information to the decision-maker on the possible pitfalls that can arise by scoring different factors by its relevance to implement the abatement option.

By doing this master thesis I had the privilege on interviewing inquisitive minds that were looking to make a change, not just in Mexico, but in the world. I always explained my research and the goal of using the Y-factor was to understand why certain paths to reducing GHG emissions were not followed. I believe that the discussions in the interviews helped me in understanding the underlying complexities of taking decisions and that the use of the Y-factor method as an added resource from

the marginal abatement cost curve is not only useful but better portrays the current situation of each of the abatement options analyzed.

6.4.2 Academic Reflection

The implementation and development of the Y-factor was first proposed by Chappin in 2016 and then research complementation arise from the likes of Cheung (2018), and Arensman (2018) by refining the current method. Soana (2018) managed to construct the first reliable Y-curve utilizing interviews to validate the scores proposed. This investigation continues the line of research with the novelty of applying the Y-factor to a case-study. Mexico was the country selected, it was a good test for the Y-factor to see the differences between making a global reliable abatement curve and doing a case-specific abatement curve considering the country's characteristics and the challenge that is to investigate a third-world country while also gather insights on the current situation of the country. Overall, the method had good reviews from the experts that were contacted; they highlighted the value of looking beyond the financial constraints and having a more robust approach to defining the factors that prevent from pursuing certain abatement options.

The positive results and the construction of the validated Y-curve should serve as an example of the replicability of the Y-factor, as well as, a starting point for analyzing countries with high abatement potential but that have not shown the desired progress. It is a useful tool to uncover what is hampering the implementation of the abatement options and other researchers or policy-makers should be aware to not based decisions only on financial data like the MAC but rather in a more well-rounded approach that can picture the whole scenario.

I think the intentions of the Y-factor are to improve current decision-making and complement the existing MAC curve to go beyond the cost perspective. I advise to use the Y-factor when trying to go beyond the superficial understanding of an abatement option and understand the underlying mechanism of why any given option has not been pursued. I like the user-friendly nature of the method and the easy to understand way of presenting the results, this helps keep perspective and add understanding of which factors hamper progress. In general, I endorsed the benefits of using the Y-factor and believe that it is a tool with potential to be a step in the decision-making process for policy makers.

SECTION 7
References

CONTENT

7. References

07.

7. References

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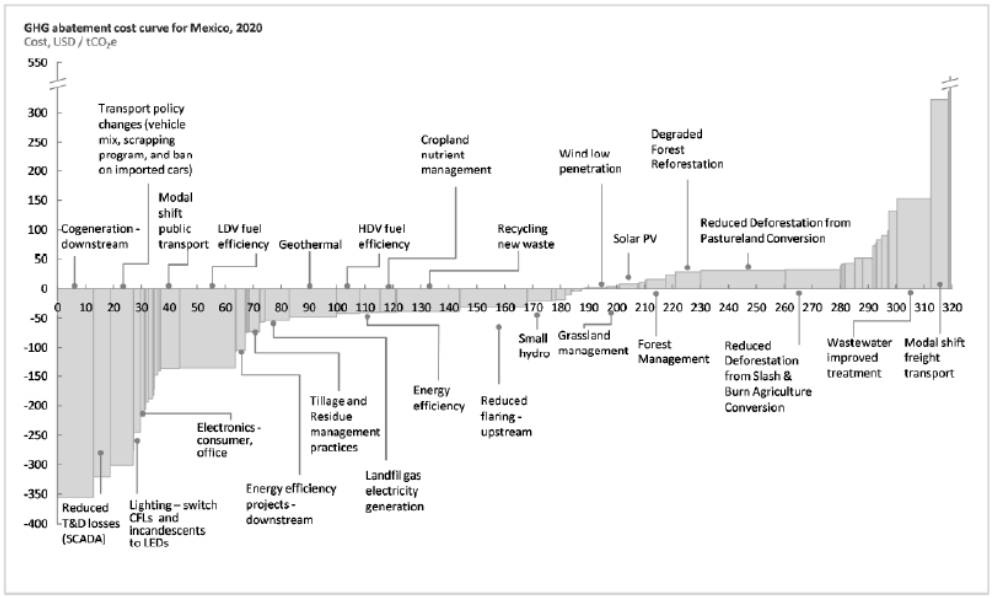
Appendix A: Abatement options selections

Mexico MAC Curve

Figure 1. GHG Abatement Cost Curve for Mexico, 2020



Source: MLED, 2013

Abatement option	Cost USD/tCO2e	MAC Ranking
Cogeneration downstream	-350	1
Reduce T&D losses (SCADA)	-320	2
Transport policy changes	-300	3
Lighting switch to LEDs	-250	4
Electronics-consumer office	-220	5
Modal shift public transport	-140	6
LDV fuel efficiency	-140	7
Energy efficiency projects	-110	8
Tillage and residue management practices	-70	9
Geothermal	-55	10
Landfill gas electricity generation	-50	11
Energy efficiency	-50	12
HDV fuel efficiency	-50	13
Cropland nutrient management	-50	14
Recycling new waste	-45	15
Reduced flaring-upstream	-40	16
Small hydro	-30	17
Wind low-penetration	0	18
Grassland management	5	19
Solar PV	10	20
Forest management	15	21
Reduced deforestation from slash & burn agriculture conversion	40	22
Degraded forest reforestation	40	23
Reduced deforestation from pastureland conversion	45	24
Wastewater improved treatment	150	25
Modal shift freight transport	400	26

The data from the abatement cost table was obtained through the figure GHG Abatement cost curve. The data is an approximation an investigation reveal that the original publisher of the curve (USAID)

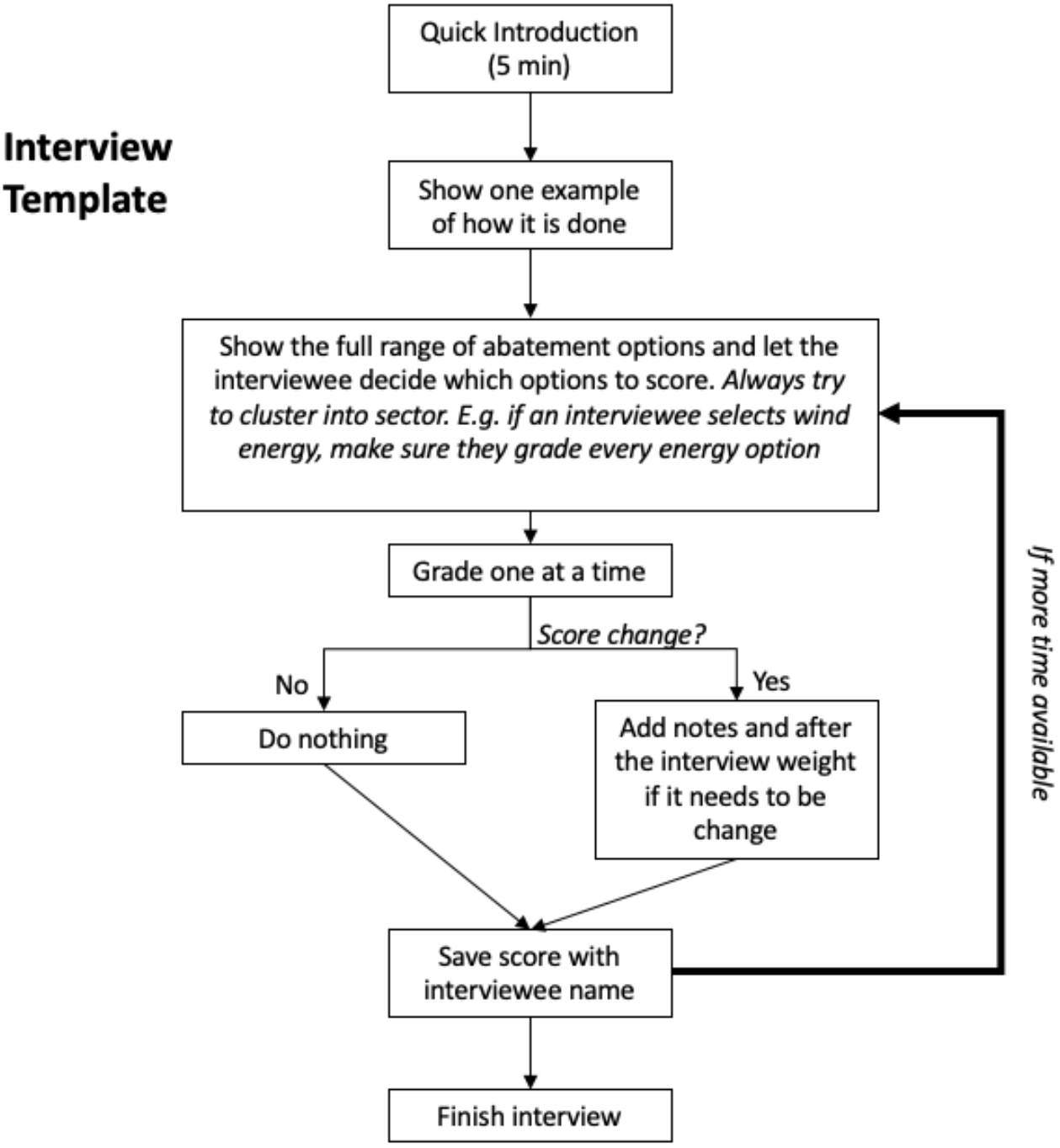
through their MLED program has remove the content of the document were the figure was originally created. The figure was obtained by Rebolledo et al (2016).

Abatement options shortlisted through Y-factor

Option	Sector	Preliminary Y-curve	McKinsey's Abatement Cost
Insulation retrofit commercial	Building	16	< 0
insulation retrofit residential	Building	17	< 0
Building efficiency new-build	Building	10	< 0
Coal CCS new-built	CCS	17	> 0
Iron & steel new-built CCS	CCS	17	> 0
Coal CCS retrofit	CCS	18	> 0
Gas plant CCS retrofit	CCS	18	> 0
Iron & steel retrofit CCS	CCS	18	> 0
CCS direct energy retrofit	CCS	18	> 0
PV panels homes	Energy	10	> 0
High penetration wind	Energy	11	> 0
Small hydro	Energy	7	< 0
Geothermal	Energy	19	< 0
Reduced slash and burn agriculture conversion	Forestry & Agriculture	17	> 0
Reduced intensive agriculture conversion	Forestry & Agriculture	17	> 0
Reduced deforestation from timber harvesting	Forestry & Agriculture	17	> 0
Reduced deforestation from pastureland conversion	Forestry & Agriculture	17	> 0
Cropland nutrient management	Forestry & Agriculture	8	< 0
Grassland management	Forestry & Agriculture	8	> 0
Rice management	Forestry & Agriculture	8	< 0
Agronomy practices	Forestry & Agriculture	8	> 0
LDV gasoline bundle 4	Fuel	9	< 0
LDV gasoline bundle 3	Fuel	9	< 0
Bioethanol lignocellulosic	Fuel	9	< 0
Lighting switch to LEDs	Household	5	< 0
Residential electronics	Household	8	< 0
Residential appliances	Household	8	< 0
Clinker substitution by ash	Industrial Processes	12	< 0
Efficiency improvement other industry	Industrial Processes	13	< 0
Energy Efficiency 1 iron and steel	Industrial Processes	9	> 0
Motor systems efficiency retrofit	Vehicles	10	< 0
Cars full hybrid	Vehicles	10	< 0
Air transport	Vehicles	18	< 0
Motor systems efficiency new	Vehicles	8	< 0
Waste recycling	Waste	13	< 0
electricity from landfill gas	Waste	10	< 0
Composting new waste	Waste	11	> 0

The table above is shortlist of the initial 218 abatement option selections provided by Mckinsey and the subsequent reduction made by Chappin (2016) further analyzed by Soana (2018) for the abatement options that were selected when doing he's dissertation of validating a global Y-curve.

Appendix B: Interview Template



Appendix C: Extended Interview Results

1. Interview José Antonio del Río

	C&F			MA Comp			Physical In.			Behavior			Notes
Abatement Option	C1	C2	C3	M1	M2	M3	P1	P2	P3	B1	B2	B3	
Nuclear Energy	2	2	2	1	1	1	2	0	2	1	2	0	Government does not necessarily depend on other actors, if you want to build a nuclear plant there. There have been talks about a new nuclear plant but have never materialized. Technology uncertainty should be high given the disasters that have happened worldwide. Absence of knowledge score is regarding safety measures.
Geothermal Energy	2	2	1	2	2	1	2	1	1	0	1	1	Geothermal energy has good potential, we have a one big plant in the country and some new projects coming along. In the future a well-planned project should be attractive for investors and provide a good opportunity for investment.
Low-penetration wind	2	1	1	2	2	1	1	1	1	0	1	0	A lot of resources are being pushed to develop wind energy in Mexico, main issue is that biggest investment is located in one state, Oaxaca. There are plans for this technology to be the main renewable energy provider. Payback time should be a 1 if managed properly, and it shouldn't require a change in behavior.
Small Hydroelectric	2	2	2	2	2	1	2	1	0	0	2	2	Mexico does not possess a lot of natural water movement besides some rivers. We do not have a lot of opportunities to build a hydroelectric as freely as in other countries. Also, there has not been a government push in this renewable energy to make it easy to find investment.
Coal CCS retrofit	2	2	2	2	2	1	2	2	2	1	2	2	This option is not been discussed in government circles, they believed it is too much an investment for the expected results. This should be the least likely option to consider.
Coal CCS New-Built	2	2	2	2	2	1	2	0	1	1	2	0	As new-built there is no disturbing in regular operations and change in their behavior. New administration is pushing to have a new-built coal plant instead of pushing on developing renewable energies.

2. Interview Fernando Canut

Abatement Option	C&F			MA Comp			Physical In.			Behavior			Notes
	C1	C2	C3	M1	M2	M3	P1	P2	P3	B1	B2	B3	
Lightning switch residential	1	0	1	0	0	0	0	0	0	1	0	0	Mexican society is not long-term planning, general population do not invest if they do not see an immediate change. If this option is serious the best way is to only sell LED's and start decreasing other type of lightning periodically.
Nuclear Energy	2	2	2	2	1	1	2	0	2	1	2	1	Personally, I think this type of energy is not sought after in the country. Previous government administrations develop frameworks on reducing emissions, but nuclear plants did not figure out. We have a reliable plant in Veracruz which has been functioning a long time without much trouble. if another nuclear plant is built there at least should be a change in behavior regarding safety measure of the town that it is built as well as radioactive waste management. Although nuclear plant if often consider a potential hazard so i think that leaves an uncertainty in using the technology.
Geothermal Energy	2	2	2	1	2	1	2	1	1	0	1	1	Geothermal energy has been an idea circling around Mexico a long time, I think the first geothermal plant in America was built in Mexico. The dependence on other actors is not as extreme, there are already on-going projects that are on track to be successful- I think the biggest challenge is in the investment, both quantity and timeframe to recoup your money is still a big factor when investing in the type of renewable energy compared to wind turbines.
Low-penetration wind	2	1	1	2	2	1	1	1	1	0	1	0	Lots of projects have been approved for the building of wind turbines, Oaxaca is now the leading state, but states in the middle of the country are going to catch up fast. Given the current condition of the technology I expect the payback time to be less than 12 years. Also, I do not see any change in behavior after building the wind turbines, if they produce electricity as expected there should be no change, hence the value of 0 in that regard.
Small Hydroelectric	2	2	2	2	2	1	2	1	0	0	1	2	Right now building a hydroelectric is not a priority so it is not that easy find a suitable actor capable of financing its investment.
Home Solar Photovoltaics	2	1	1	1	1	0	2	0	1	1	0	1	This is an expanding business, more people are aware of solar panels and are pursuing it's installation, Mexico is importing a lot of its solar panels from China. The score of dependence on other actors should be a one considering that Mexico does not produce a high percentage of the panels and any disruption in the supply chain could change the market complexion.
Electricity from Landfill gas	2	1	2	2	1	1	1	0	0	0	1	0	This is a good option to do, although high investments might off-put investors. You are too dependent on other actors like who handles the waste and where are they dumping it. There should be no change in behavior but rather a clear framework for role division and the activities that have to be done. If waste composting is done correctly this could become attainable and attract some investors for doing it.
Waste composting & recycling	1	1	1	2	1	1	2	1	0	0	0	1	Waste is a big issue in Mexico City, landfill is where most of the garbage goes to. Also, this abatement option is being done, just not at a high level and with mixed results because there is no focus on doing it. There should be a slight issue of who does what, and also a small change in behavior because, as I said we are doing this but we are not pushing it to be as successful as it should be. Also, the physical environment should change substantially for the good if this is done correctly.

3. Interview A

	C&F			MA Comp			Physical In.			Behavior			Notes
Abatement Option	C1	C2	C3	M1	M2	M3	P1	P2	P3	B1	B2	B3	
Agronomic practices	1	0	1	0	1	0	0	1	1	1	0	1	Training costs required, Mexico has a lot of small-land farmers this makes it difficult to improve the current practices and might also have trouble finding investment. The best way for this option to be optimized is by having several farms be together and produce in bulk instead of the current micro-ownership system.
Reduced Deforestation	1	1	2	1	2	2	0	0	0	1	0	1	This option is really tricky because of the lost cost of opportunity in maintaining forests instead of using the resources or even urbanizing the area. Personally, I see it quite difficult to find private investors jumping to this type of business, so everything falls to the government and money allocation is always a conflict of interests. Right now, the government gives like a small payment or allowance to some communities to take care of the forests, but it is really hard for them to keep track of any illegal activity. The best way to improve this situation is to enforce stricter regulations to offenders, because current ones are not working, and illegal logging continues to be an issue.
Grassland Management	1	0	1	1	1	1	0	0	1	1	0	1	Investment costs should be increased, just for the education and the learning curve on how to manage the grassland. For the same reason as in agronomic practices people just have small estate farms so it is hard to finance the investment if you do not have a big lot of land. They have some good techniques of grassland management in the states where meat is produced, Mexico has no issue with sun power for grass to be growing year-round, but water management is still a big issue.
Electricity from Landfill gas	2	1	1	1	1	1	1	0	0	0	1	0	New regulations expected to take place in big cities, this type of energy gathering is not as fancy as investing in a wind turbine or solar power, therefore it is not used leading to be hard to find financing. Also, I think this option those not require a change in behavior.
Waste composting & recycling	1	1	1	2	1	1	1	1	0	0	0	1	In Mexico, trash is only separated in two ways: organic and inorganic. This helps in the composting since every organic waste should be jointly placed, main problem is that almost everything is on small plastic bags leading to a not so efficient comporting process. The main issue is actually with recycling because trash is just put together in the inorganic pile, schools have installed this recycling centers as well as companies but there is no strong motivation for every day doing all this waste separation and getting them ready for recycling.

4. Interview Jorge Escobar

	C&F			MA Comp			Physical In.			Behavior			Notes
Abatement Option	C1	C2	C3	M1	M2	M3	P1	P2	P3	B1	B2	B3	
Air transport	2	0	0	1	1	0	0	0	1	0	1	1	The money for investment in new bio-fuels has to be scored as a 2 considering that Aeromexico (Mexico's biggest airline carrier) does not spend a lot on new research fuels and is dependent on what other parts on the world discover. If Mexico were to enter the race for looking for alternative fuels big investments need to be made and a partnership with national universities could be the best way to do it. In parallel with this the diversity of actors involved should increase to a 1 since they will have to be reliant in different actors and potential patent conflicts could rise because of this.
Modal Shift Freight Transport	2	1	0	2	2	2	2	2	0	0	1	2	This option needs a huge amount of investment. I personally do not see it as feasible consider the current situation with the different means of transport, they need cooperation, upgrade and build new infrastructure specially for railways and port improvement. The expected pay-back time should increase a be somewhat between 5-12 years depending on the amount of investment needed. It is probable that responsibilities could become a mess and therefore everybody would be pointing fingers at each other on who's fault is. The physical landscape should change a lot with the new constructions of railway and transport hubs needed for this.
Transport Policy Changes	2	1	1	2	2	1	2	2	0	0	1	2	This is a city measure, it could be implemented in any of the 5 metropolitan areas of the country but the biggest beneficiary would be Mexico city, the amount of players involved can make this really difficult to implement because a joint coordination effort needs to take place and specially offer public transport options when the cars are not allowed to be on the road. If done right, it should also change the physical picture of the city with added stations and new ways of connecting people. In consequence disturbances will be frequent and a reluctance to change is definitely going to arrive from different players.
Heavy duty vehicles emission reduction	2	1	1	2	0	1	0	0	1	1	1	0	Even though the HDV market is highly profitable for Mexico, I do believe that it will be hard to find financing for the research of the emission reduction since the Mexican government has very weak policies to treat this issue in the sector. If someone outside (lie universities) is hired to try to solve this issue there could be potential trouble in dividing the tasks of research and lead to some issues about objectives that is why a score of 1 is given. As in every research proposal the actor cannot know every fact available so i believe there will be some absence of knowledge in this situation.
Light duty vehicle emission reduction	2	1	1	2	1	1	0	0	1	1	0	0	Same as the LDV for the difficulty of financing and the absence of knowledge of actor and the division of roles. In addition to this I think there could be certain conflicts since this is an open market situation where the cars go straight to the public and this could end with the different actors in conflict for potential compensation.
Battery Electric Vehicles	2	1	1	2	0	1	1	0	1	1	2	2	I believe that electric cars are new to the market, in Mexico we do not have the infrastructure to change from a fuel-based to electric and the buyers will probably buy them because it's the new thing rather than because they are knowledgeable-

Hybrid Vehicles	2	1	1	0	0	0	0	0	0	0	2	0	Hybrid vehicles are different from the electric because they have been in the country and functioning or a while now. The range of cars is really limited, and the government does not give extra benefits to buy one in comparison to normal cars unless you are a cab driver; this means that for a normal person financing is equally hard to obtain from a normal car than an environmentally friendly one.

5. Interview B

	C&F			MA Comp			Physical In.			Behavior			Notes
Abatement Option	C1	C2	C3	M1	M2	M3	P1	P2	P3	B1	B2	B3	
Coal CCS retrofit	2	2	2	2	2	1	2	2	2	1	2	2	I agree with the grading that you wrote. Really difficult for the government to pursue this initiative but a problem nonetheless.
Coal CCS New-Built	2	2	2	2	2	1	2	0	1	1	2	0	This option, since it is for new-built plant should not interfere with the regular operation and also should not have a change in behavior.
Lighting switch residential	1	0	0	0	0	0	0	0	0	0	0	0	I think it should not be hard to find financing for this because it is a small investment with huge benefits. Also, I think there is no absence of knowledge since LEDs have been proven to be more reliable that regular lightbulbs.
Home Solar Photovoltaics	1	1	1	0	1	0	1	0	0	1	0	1	I think the investment cost for this can be considered medium because the materials have become cheaper and it is not a novelty anymore, plus the benefits should help replenish the costs. It will change the physical aspect of your home that is why a 1 is proposed the technology uncertainty is a 0 for me, again technology in this aspect have proven to be reliable with the country having so much hours of sun all year round.
Electricity from Landfill gas	2	1	2	2	1	1	1	0	0	0	1	0	There are different actors involved in this and you are dependent on the federal government as well as municipal government, and even state governments depending on where the landfill is. I also do not expect any change in behavior since there will not be a radical change in the landfill.
Waste composting & recycling	1	1	1	2	1	1	1	1	0	0	0	2	The main issue I see with the grading is who is responsible for what. Will the government have enough special containers for the different trash, or will they rely on people separating the trash. I think it should be a combination of the two but potential issues because of uncertainty of responsibilities could arise.

6. Ximena Celis

	C&F			MA Comp			Physical In.			Behavior			Notes
Abatement Option	C1	C2	C3	M1	M2	M3	P1	P2	P3	B1	B2	B3	
Agronomic practices	1	1	1	0	1	0	0	0	1	1	1	1	You should take into account that most of Mexico's farmers have small plots of land, less than 10 hectares so the money that they can get if they harvest something is not a huge amount. Therefore, the cost related measures should be proportional to the actors who is responsible to invest, in this case the farmer that is why for some farmers investing in new methods is a lot of money especially the one's with small plots. On average we can say that the investment cost required should be medium. Meanwhile the expected pay-back time is difficult to calculate because it depends if your product is of export quality which in that case should be less than 5 years but if not it can take longer to see a fruitful contribution for your investment I would say a bit more than 5 years depending on how many crops you can harvest in a year. Also, we are trying to implement programs for the "little farmers" so that they know the best practices in the industry but the reality is that it is hard to gather all the farmers in one place and we cannot go one-by-one teaching them, so the easiest way is for them to pay for a course or go a conventions and learn more. If the idea of agronomic practices is to improve them, they will not affect the regular operations. For the frequency of opportunity, I need to change the score because the small farmers cannot afford to change their practices and avoid using fertilizers from one moment to another because it can disrupt the size of their crops I think this should be a planned decision and it cannot be done any other day.
Reduced Deforestation	1	1	1	1	2	2	0	0	0	1	0	2	This is a tricky option, because it is the avoidance of killing the forest. We have had some conflicts in this area because our current programs pay the local communities for taking care of the forest but if something happens, they almost never call the police and it is really difficult to find out if something is happening. The responsibilities of the people taking care are not clear and it leads to many communication issues. Also the current mentality is to attract money to industries so if the industry wants to establish in a forest that is not protected they most likely will be able to do it if the economic benefits exist, we need to change the behavior of what we want to do and protect the forest that we currently have because we have low replenish rates and in the future it could be a problem with the air pollution of the country.
Grassland Management	1	1	1	1	1	1	0	0	1	1	0	1	Most of my comments from the agronomic practices regarding the financial issues also apply to the grassland management. Even though the economic activity is different the plot sizes and the resources available are similar from one to another and the scores in my opinion should be the same.

7. Edgar Rubí

	C&F			MA Comp			Physical In.			Behavior			Notes
Abatement Option	C1	C2	C3	M1	M2	M3	P1	P2	P3	B1	B2	B3	
Nuclear Energy	2	2	2	1	1	1	2	0	2	1	2	2	I think nuclear energy is kind of a taboo topic in some places, for us we only have one plant and we haven't had any issues with it, but normally nuclear energy has some sort of bad reputation and it will be dependent on the community on the potential site of the plant. If constructed there will be a change in behavior specially for safety measures in the municipalities near the imaginary nuclear plant. I personally think that there are some technological uncertainties with this energy since it has shown through cases around the world that one bad decision can lead to catastrophe, and this also leads me to believe that an absence of knowledge is the reason for these failures of nuclear plants.
Geothermal Energy	2	2	2	2	1	1	2	1	1	0	1	1	The only thing I would change from this scoring is the diversity of actors involved, you always have to take into account the Federal Energy Commission when dealing with any sort of energy topic and they have a lot of power in the country that could lead to conflicts.
Low-penetration wind	2	1	1	2	1	1	2	1	1	0	1	0	The expected pay-back time should be low, I wouldn't bet on an investor recovering the money in less than 5 years, but it is realistic to expect it before 10 years. The only conflict I can see for all the renewable energy distribution is the transportation costs and who will be responsible for that, the current centralized way of distribution makes it tricky for different players in the energy sector. The physical changes I believe are massive because investors are not installing one or two turbines but rather a whole complex of them especially in the southeastern states in the Istmo. I do not think a change in behavior is required for the implementation of the wind energy, maybe for the local communities where the capacity is installed but it is highly debatable.
Small Hydroelectric	2	2	2	2	2	1	2	1	0	0	1	2	I agree with most of the scores but right now it will be hard for an investor to finance a hydroelectric, most of the permits are going for wind energy and there is a growing trend to invest in solar and even geothermal.

8. Edgar Fabris

	C&F			MA Comp			Physical In.			Behavior			Notes
Abatement Option	C1	C2	C3	M1	M2	M3	P1	P2	P3	B1	B2	B3	
Air transport	2	0	0	2	1	0	0	0	1	1	1	1	The air industry in Mexico has been through a lot of changes with big players becoming bankrupt and there is always hesitation with them since the last 10 years that it happened. This has lead to them been careful in what they invest and investing in potential bio-fuels for the air transport in Mexico will be really costly but they could manage to find proper investment and if one correctly have a good return on investment. Also to do this the "safe" bet is to invest through universities labs or even students researching in chemistry or similar topics, I think they are quite dependent on something happening outside of their own research team for this to be fruitful. This could very well lead to some conflicts down the road, but I think the benefits should be enough. The other factor that I would change is the absence of knowledge of factor since it is clear that a new bio-fuel will not be tested in a big scale and there could be issues with it.
Modal Shift Freight Transport	2	2	2	2	2	1	2	2	0	0	1	2	To be honest, this option is quite hopeful. The country depends a lot in ground-transportation involving trucks from every size and it can be advantageous to use a different type of logistic system. It will be really expensive because not every transport sector is up to the standards and new infrastructure must be built. It will also change the physical embeddedness if new structures arise and even a logistics hub could be a good idea, the closes thing we have is the airport and it is a highly conflicted road area.
Transport Policy Changes	2	1	1	2	2	1	1	1	0	0	1	2	This is an option that is in constant change especially in the city, the reality is that Mexico city is so big that no policy will heal all of its problems but they have not come up with a smart solution to treat this issue. The main blockers are the people in the city itself and the different groups they represent, you have the people going to work, moms leaving the kids in school, cab drivers, truck drivers. The amount of conflicts and actors involves is so diverse that there will always be someone opposing any policy that can be proposed.
Heavy duty vehicles emission reduction	2	1	1	2	0	0	0	1	1	1	1	1	It is hard to find financing for these measures if there are no regulations, but the industry should be able to cope with most of the costs. Depending on the changes, for example having electric trucks could lead to changes in the regular operation but it really depends on what are those changes since it is uncertain, I will leave the score with a 1. This can also lead to a change in behavior on when and how to drive, and at first there will be issues because not everyone will know how to do it that is why I think both of them are a 1. I am assuming any change, if the changes is only in improving the engine this measures are a 0.
Light duty vehicle emission reduction	2	1	1	2	0	1	0	0	1	1	0	0	For the LDV is the same for the financing investment, it will be dealt internally and if you want a loan from banks or investors it should have a medium difficulty to find. I think that are some uncertainties in the responsibilities of the industry that affect some of the quality because a lack of a clear framework up to the standards of the US is missing. Also every new improvement comes with uncertainty that is why a give a 1 for absence of knowledge of actor.

Battery Electric Vehicles	2	1	1	2	1	1	1	0	1	1	2	2	Electric cars are a hot topic in the country, and everyone talks about them but nobody really buys them because there is a lack of infrastructure for this cars. I think the will be some conflicts especially in the price of charging your car, home electricity is quite cheap compare to other countries but I wonder what the CFE would charge, right now they have some sort of subsidy but if the market grows I do not think they can hold current prices and this could potentially lead to conflicts. Also I see an absence of knowledge from the buyer and what it represents the change from fossil-based to electric car, the people that buy this cars that enough income but if it becomes widespread I think several issues will arise.
Hybrid Vehicles	2	1	1	0	0	0	0	0	1	1	2	0	I think it is hard for a potential buyer of a hybrid to find better financing compare to buying any other car. There is no added bonus minus the possibility to drive every day regardless of air pollution. I think there is always uncertainty with technology because it is never a given that it will work perfectly. For the absence of knowledge is the same as what I said for electric cars.