Assessment of the sustainability of Mexico green investments in the road to Paris

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ABSTRACT

Mexico is expected to rank among the top-ten largest economies in 2030 and to become the 6th in 2050. According to EDGAR database, in 2012 it was the second largest polluting country in Latin America and the 10th in the world, regarding GHG emissions. To meet the Paris Agreement, Mexico's INDC - "Intended National Determined Contribution"- is committed to reduce unconditionally 25% of its GHGs and Short Lived Climate Pollutants emissions (below BAU) for the year 2030. Since the strategy to achieve the mitigation goals needs an increase in renewable energy sources, Mexico's national climate change policy package has already been launched. A keystone of Mexico's green strategy is the increase in renewable energy sources throughout an ambitious program that imply the deployment of 13.5 GW of wind energy, 1 GW of biomass, 0.7 GW of geothermal energy, 1.75 of hydropower and 10.4 of solar energy in the period 2018-2030.

These "green" investments would imply an expected mitigation around 63 Mt CO_2eq, once the new facilities are fully deployed. However, the construction phase as well as the operation and maintenance will increase emissions. In this context, this paper assesses the green energy investments proposed by Mexico for the period 2018-2030, comparing its impact on production, value added, and employment by qualifications, materials, land use, water and CO_2eq emissions with the desirable REmap scenario proposed by IRENA, compatible the Paris Agreement goals. For this purpose, the input-output analysis in a multiregional framework is used, estimating the direct, indirect and induced effects of Mexican policies. Finally, a counterfactual analysis is undertaken by reallocating the production electricity mix according to the share of new RES deployment and comparing it to the Mexican economy in 2011 from a TBL approach to estimate to what extent CO_2eq emissions reductions from these green investments deployment are contributing to its commitment in the road to Paris Agreement.

1. Introduction

Mexico is among the fifteen largest economies in the world. The country is expected to rank to the top-ten largest economies in 2030 and to become the 6th in 2050, overcoming countries such as Japan or Germany or United Kingdom (Hawksworth and Chan 2015). Unfortunately, Mexico's growth is being reached at the expense of environment and society, becoming one of the most unequal OECD countries (OECD 2013). Mexico's compound annual growth rate was 4.8% GDP in the period 2010-2017 and it is estimated that the Mexican economic growth will lead to an increase of CO_2 emissions (Gobierno de México 2015). Besides, air pollution is the major environmental concern of the population and imposes significant costs on the economy (OECD 2013). Although Mexico has one of the lowest levels of CO_2 emissions per capita in the OECD, in 2016, Mexico had the world's 12th-highest CO_2 emissions from fuel combustion and the country is highly exposed to climate change risks (IEA 2015, 2016). Due to the fossil fuels-intensive primary energy mix (Guevara et al. 2018), CO_2 emissions from electricity and heat production in Mexico accounted for 44% of total emissions from fuel combustion in 2014 (IEA 2014) being the second most pollutant activity in Mexico, after transportation.

In this sense, the electricity industry is a key sector in the achievement of GHG emissions reduction and the self-sufficiency of energy supply (Santoyo-castelazo, Stamford, and Azapagic 2014). Energy efficiency and renewable energy sources (RES) are the two main pillars of the energy transformation. Together, they can provide 90% of the energy-related CO_2 emissions reductions in the world that are required to maintain warming bellow 2ºC (49% and 41%, respectively) (IRENA 2018).

In 2015, Mexican RES total primary energy supply (TPES) was 15.5 out of 187.3 million tonnes of oil equivalent (Mtoe) (8.3%). In terms of electricity generation, 46.7 TWh (15.2% of total electricity generation) came from renewable sources (IEA 2017). Mexico is endowed with abundant natural resources (Huacuz 2005). The country is a leader on geothermal energy, and the potential on hydropower, wind and solar energy is remarkable (Alemán-Nava et al. 2014; IRENA 2015). Besides, Mexico has been one of the most active non-Annex I parties since the ratification of the Kyoto Protocol in 2000, making significant efforts in the communication of the national inventories on GHG emissions. It also became the first emerging economy to submit its Intended National Determined Contributions (INDC) within the Paris Agreement (NRDC 2017). However, the share of renewables in electricity production has not increased over the years, but even declined from 20% in 2000 to 18% in 2010 (OECD 2013). This phenomenon must be reverted. To meet the Paris Agreement, the Sustainable Development Goals (SDGs) and the Mexican National Strategic Plan for Development (NDP), Green investments in fostering renewable energies are needed. The concept of Green investment has not been dimensioned due to differences in the definition of the term "green", although in the literature it is similar to clean, sustainable or climate change investment. The definition by (Eyraud et al. 2011) refers to green investment as "the investment necessary to reduce greenhouse gas and air pollutant emissions, without significantly reducing the production and consumption of non-energy goods".

The purpose of the present research is double. First, it focuses on detailed RES deployment (nuclear energy excluded) planned by the Mexican Government in order to achieve the targets on installed capacity of low-emission energy supply and emissions reduction. In addition, the mitigation strategy should be seen as an opportunity to improve the development of the economy, and finally reduce poverty and inequality in line with the Sustainable Development

Goals (SDG). To do so, a triple bottom line (TBL) (Foran et al. 2005; Kucukvar, Egilmez, and Tatari 2014) {Zafrilla, 2014 #254}{Monsalve, 2016 #396} is performed to assess the socioeconomic (green jobs, salaries and profits, value added and total production) (Jarvis, Varma, and Ram 2011), and environmental impacts (material footprint, land use, water consumption and carbon emissions) (Steen-Olsen et al. 2012) of the programmed investments on RES and the operation and maintenance expenditures involved. Secondly, we want to answer the question, is Mexico making a relevant performance in achieving wellbeing in terms of emissions reductions, economic growth and green job creation through RES deployment? The green investments assessed in this research would imply a CO_2eq expected mitigation once the new facilities are fully deployed. It will also create new jobs across many sectors that contribute to sustainable development. However, their construction phase as well as their operation and maintenance will increase emissions that should be accounted in order to achieve the planned emissions peak. To tackle this question, two scenarios are compared to a business-as-usual (BAU) scenario where current fossil fuel-intensive structure in the energy mix consumption is assumed to prevail at the current level. The first one captures the changes in the energy mix that would occur in the long-term due to Mexican policy packages submitted up to the date. The second scenario proposes an ideal final demand boost in RES so that the role of Mexico fits the Paris Agreement goals. We assess the net impacts of these two scenarios, subtracting the previous impacts calculated, in terms of CO_2eq emissions reductions, materials, water, land, value-added and job creation. The model we develop is an extended multiregional input-output model that allows considering the direct, indirect and induced impacts of the RES deployment in Mexico including all the global value chains.

Some researches assessing Green investments have been developed, exploring in quantitative terms their macro-economic implications. The methodological approaches are varied (see the review by {Jenniches, 2018 #827} or by (Cameron and van der Zwaan 2015) regarding the employment impact) ranging from life cycle analysis (see for instance, (Stamford and Azapagic 2014)), to the most widely utilized approach, the input-output analysis. Research on green investments and employment are extensive (Hondo and Moriizumi 2017; Markaki et al. 2013; Markandya et al. 2016; Tourkolias and Mirasgedis 2011). In the case of Mexico, (Rodríguez-Serrano et al. 2017) analyses the economic, environmental and social impacts of using Solar Thermal Electricity (STE) instead of Combined Cycle from a Framework for Integrated Sustainability Assessment perspective, quantifying TBL results on an alternative scenario where STE power plants in 2030 have substituted the combined cycle of natural gas. These researches use input-output models where all different power generation technologies are included in an aggregated electricity sector, assuming that all these technologies have the same production structure. In real world, cost structures and employment per unit of output in RES production are greatly different from conventional technologies. Thus, these results in a lack of information regarding the characteristics of each individual renewable power generation technology (Hondo et al, 2018). The present research is a novel analysis on the basis of an extensive package of RES deployment in Mexico, using a multi-regional input-output table (MRIOT) that differentiates between types of energy production, solving the limitations of previously mentioned analyses.

The rest of the paper is as follows. In the second section, an overview of RES, the Energy Reform and Climate change in Mexico is exposed. Section 3 focuses on methods and data sources. In section 4, the main results are presented. Section 5 concludes with a final discussion.

2. An overview of Climate Change, the Energy Reform and RES in Mexico

The Paris Agreement is the substitution of the Kyoto Protocol and set the target to avoid increasing the global average temperature 2ºC above the pre-industrial levels. Many developing countries have presented unconditional and conditional GHG reductions. Unconditional reductions meant to be undertaken regardless the international overview. Conditional reductions could be accomplished if global agreements are carried out. These agreements address relevant issues including international carbon price, carbon border adjustments, technical cooperation, access to low-cost financial resources and technology transfer. In this sense, Mexico submitted its Intended National Determined Contribution (INDC) that consisted of a GHG and short-lived climate pollutant (SLCP) reduction target of 25% (unconditional) to 40% (conditional) below business-as-usual by 2030. The unconditional target implies reductions in GHG emissions by 22% and in SLCPs by 51% by 2030. It also implies a peak in net emissions in 2026 and a reduction in emissions intensity (CO_2/GDP) by 40% below 2013 levels by 2030 (IEA 2017). In a nutshell, Mexico has proved to be a country committed with Climate Change.

During the last years, the country has launched a package of programs and initiatives to fight against GHG increase and achieve economic sustainability (see Table 1). In terms of energy, with the 2014 Energy Reform, Mexico is searching for a cleaner energy system that allows the country being self-sufficient, clean and efficient in the generation, transmission and distribution of electricity (SENER 2015). This package has been understood as an ambitious structural reform that has the potential to raise productivity and unleash growth in the medium term (IEA 2017). The steps that Mexico is doing towards Green Growth and the Paris Agreement commitments can be separated in two main categories: *i)* Energy; *ii)* Climate Change. Both categories are complementary and compatible with each other and deeply entrenched in Mexico's current policy making. In terms of RES investment, in 2010 the country achieved the largest absolute increase in Latin America, being Hydropower the largest source of renewable electricity followed by geothermal energy (OECD 2013). Despite being the world's fifth largest geothermal power installed capacity country and having a huge potential on wind and solar energy, Mexico is currently a country that depends on fossil fuels. Increasing RES generation would help Mexico in: *1)* reducing GHG emissions, *2)* diversifying energy supply, shifting from a carbon-intensive energy structure towards a sustainable one, *3)* generating energy savings, and *4)* lower harm to health (IRENA 2015, 2018). Within the National Strategic Plan for Development (NDP), along with the Energy Reform, the General Law on Climate Change (LGCC, 2012), the Energy Transition Law (LTE, 2015) and the Law on Electric Industry (LIE, 2014) are the three pillars in promoting a higher participation in RES and pursuing the commitments acquired at the COP21 (SENER 2018b). Both planning (e.g. the Energy Sectoral Program, PROSENER), economic (e.g. the Fund for Energy Transition and Sustainable Energy Use, FOTEASE or the clean energy auctions) and R&D (e.g. the Mexican Energy Innovation Centres, CEMIEs) instruments have already been initiated (SENER 2017).

To assess the RES deployment in the future, this paper focuses on the National Electricity System Development Program (PRODESEN), which is the main long-term planning instrument for the electricity sector, based on all public and private projects to increase generation capacity, transmission and distribution activities on a time horizon of 15 years. PRODESEN investment needs are determined by SENER, based on proposals and information from the system operator National Center for Energy Control (CENACE) and the Federal Electricity Commission (CFE). Among its goals, it includes the efficiency and security energy supply, diversification of the electric power generation matrix and installation of sufficient resources to meet the objectives of Clean Energy (SENER; 2015).

Table 1

Overview of Mexico's policies and initiatives related to Energy and Climate Change

	Energy SENER	*Climate Change* SEMARNAT
Laws	Energy Reform (2014)	
	Energy Transition Law (LTE, 2015) Law on the Use of Renewable Energy and Financing of Energy Transition (2016) Law on Electric Industry (LIE, 2014)	General Law on Climate Change (LGCC, 2012) Carbon Tax (2014)
Plans Strategies	National Strategic Plan for Development (NDP)	
	Transition Strategy to Promote the Use of Cleaner Technologies and Fuels (2016)	National Climate Change Strategy (ENCC) Intended Nationally Determined Contribution (INDC)
Programs	Energy Sectoral Programme (PROSENER) National Program for the Sustainable Use of Energy (PRONASE) Special Program on the Use of Renewable Energy (PEAER 2014-2018) National Electricity System Development Program (PRODESEN) Special Program for the Energy Transition (PETE) Mexico Municipal Energy Efficiency Project (PRESEM) Mexican Energy Innovation Centres (CEMIEs)	Special Program for Climate Change 2014-2018 (PECC) National Appropriate Mitigation Actions (NAMA)

Note: Ministry of Energy (SENER), Ministry of Environment and Natural Resources (SEMARNAT). Source: own elaboration.

The investment estimations in the electric power sector for the period 2018-2030 is aimed basically at generation (83.1% of total investment), followed by transmission (9.9%) and distribution (7.0%). This research covers the RES additional generation investments predicted by PRODESEN for this interval (SENER 2018a). The program imply the deployment of 13.5 GW of wind energy, 1 GW of biomass 2.2 GW of geothermal energy, 1.75 of hydropower and 10.4 of solar energy in the period 2018-2030.

Table 2

Mexico's main green investments proposed in the power sector (additional generation for the period 2018 – 2030)

Technology		**PRODESEN**			**IRENA**		
		Installed capacity	**Total investment required (M$)**	**Annual O&M costs**	**Installed capacity**	**Total investment required (M$)**	**Annual O&M costs**
RES		*27,220 MW*	*37,199*		*76,312 MW*	*104,287*	
P.1	Wind	13,458 MW	19,151	38.1 $/kW	26,201 MW	37,285	66 $/kW
P.2	Solar PV	10,373 MW	10,851	10.7 $/kW	29,586 MW	30,949	16 $/kW
P.3	Thermosolar	14 MW	93	48.6 $/kW	1,500 MW	9,911	35 $/kW
P.4	Geothermal	685 MW	1,291	105.1 $/kW	3,374 MW	6,363	135 $/kW
P.5	Hydropower	1,750 MW	3,380	24.4 $/kW	12,858 MW	24,829	30 $/kW
P.6	Bioenergy	940 MW	2,433	- $/kW	2,793 MW	7,229	53 $/kW

Source: PRODESEN (2018), and IRENA (2015). Annual O&M costs from PRODESEN for year 2017.

To understand the impact of the Mexican expected green investments, PRODESEN proposal is compared. Renewable energy roadmaps have been developed by international institutions such as the International Renewable Energy Agency (IRENA), in line with one of the key objectives of the Sustainable Energy for All (SE4All) initiative led by the United Nations (UN) and the COP21 (IRENA 2015). The IRENA's Roadmap for Renewable Energy future (REmap 2030 Scenario) is an analytical approach for assessing the gap between current national energy plans, additional potential renewable technology options in 2030 and the SE4All objective to double the global renewable energy share in 2030 (IRENA 2015). It analyses the deployment of low-carbon technologies needed at a country-level to generate the transformation of the global energy system in order to accomplish the Paris Agreement goals in limiting the rise in global average temperatures to less than 2 degrees Celsius (IRENA 2018). It also provides indications so that the share of renewables in the global energy mix can be doubled by 2030, both realistically and cost-effectively (IRENA 2015).

When compared to REmap, PRODESEN initiative is "insufficient" to meet the COP21 targets (CAT 2018). The national initiative underperforms especially in wind and solar energy, which must be further deployed (see Table 2). According to IRENA (2015), substantial additional investment in low-carbon technologies will be required compared to the current and planned policies. The penetration for the period 2018-2030 (PRODESEN) doesn't give priority to Thermosolar, a source of energy especially promising in Mexico (Rodríguez-Serrano et al. 2017). Compared to the Reference Case (based on current and planned policies including INDCs), significant solar thermal potential is available for further deployment, especially in industry (IRENA 2015).

Table 3
Mexico's expected electricity production and installed capacity in 2030

		Electricity production (GWh)			Installed capacity (MW)		
Technology		**2017**	**PRODESEN**	**IRENA**	**2017**	**PRODESEN**	**IRENA**
RES		*50,736*	*155,272*	*279,100*	*18,988*	*46,208*	*95,300*
P.1	Wind	10,620	57,454	91,500	4,199	17,657	30,400
P.2	Solar PV	344	18,196	65,500	214	10,587	29,800
P.3	Thermosolar	0	24	3,600	-	14	1,500
P.4	Geothermal	6,041	10,930	31,500	926	1,610	4,300
P.5	Hydropower	31,848	39,246	72,000	12,642	14,393	25,500
P.6	Bioenergy	1,884	10,831	15,000	1,007	1,947	3,800
Conventional		*259,766*	*279,058*	*291,500*	*53,358*	*67,849*	*42,000*
Others (nuclear, cogeneration)		*18,661*	*39,522*	*26,200*	*2,865*	*7,969*	*3,000*
Total		**329,162**	**455,262**	**596,800**	**75,685**	**121,955**	**139,100**

Source: (SENER 2018c), and IRENA (2015). Annual O&M costs from PRODESEN for year 2017.

Depending on the projections, RES electricity production and installed capacity present different results for the year 2030. According to PRODESEN, the share of RES in electricity production and installed capacity would reach 34.1% and 37.9%, respectively. IRENA's ideal scenario raises the participation of RES to 46.8% (GWh/year) and 68.5% (MW installed). PRODESEN gives priority to Wind and Hydropower, while IRENA proposes an increase in Solar. The expected emissions mitigations also vary. PRODESEN green investments deployment is expected to contribute in the GHG mitigation so that in 2030, an overall of 138.7 Mt CO_2eq emissions would come from the electricity sector. When compared to the BAU scenario (202 Mt CO_2eq), these results in a mitigation of 63 Mt CO_2eq (SENER 2018a). On the other hand, IRENA estimates that GHG emissions in 2030 under REmap 2030 scenario would reach 175 Mt CO_2eq in the power sector. Compared to the 2030 Reference Case (254 Mt CO_2eq), these results in a mitigation of 78 Mt CO_2eq. Since the 2030 Reference Case is supposed to gather PRODESEN green investments, different methodologies are used to estimate GHG emissions. The present research chooses the national estimations to work with a common methodology. Only data related to installed capacity is taken from IRENA.

3. Materials and methods

3.1. EMRIO model

To assess the impact of Green investments, a multiregional input-output model (MRIO) has been used. The standard MRIO model (Miller and Blair 2009) quantifies economic transactions between sectors and countries all over the world including imports and exports by sector and country of origin and destination, resulting in a combined multinational-multiregional inter-industry transaction matrix. Extended MRIO models (EMRIO) have become a valuable approach in the analysis of the impact of human economic activities and in supporting related economic and sustainability policies {Moran, 2018 #792}{Wiedmann, 2013 #114}{Wiedmann, 2018 #765}. The usual extension is on the environmental issues but there is an increasing literature extending the applications to other fields:

$$x = (I - A)^{-1} y \tag{1}$$

Where x is the total production of goods and services, A is the technical coefficient matrix, $(I - A)^{-1}$ is the inverse of Leontief which represents direct and indirect effects and y is the final demand. As MRIO captures total, both direct and indirect, requirements from every sector in every country needed to satisfy final demand, we use it to calculate the total requirements that result from the green investments in Mexico. This approach has been extended as a hybrid model LCA-IO since we combine Input-Output with disaggregated data on direct and downstream requirements (construction, operation and maintenance costs) in green investments (see Eq. 2).

$$x_{GI} = (I - A)^{-1} \hat{y}_{GI} \tag{2}$$

Where x_{GI} is the total, direct and indirect impacts of green investments on the production and y_{GI} is the green investments expressed as a final demand diagonalized vector (see Eq. 3).

$$F = \hat{f}(I - A)^{-1} \hat{y}_{GI} = P \hat{y}_{GI} \tag{3}$$

Where F is the total socioeconomic or environmental effect, $\hat{f}$ is the environmental or socioeconomic diagonalized vector. Induced impacts on employment are also calculated following the Miyazawa's scheme (Miyazawa 1968). The matrix A is expanded to include the private expenditure by households as a new column and the wages of employees' row vector as a new row (see Eq. 4). New final demand vector $\hat{y}'_{GI}$ includes personnel costs. Induced effects of energy savings are not included.

$$F' = \hat{e}'(I - A')^{-1} \hat{y}'_{GI} \tag{4}$$

EXIOBASE3 has been used for the year 2011 (Tukker et al. 2013; Wood et al. 2014). This MRIOT has been aggregated to 50 sectors and 6 regions (see SI). Its socioeconomic and environmental satellite accounts, along with a novel sectoral disaggregation related to renewable power generation technologies, make EXIOBASE the most suitable MRIOT for the research purposes. An overall of 6 socioeconomic and environmental indicators have been chosen (see Table 4). We define Green Jobs as the employment generated by the investments that goes in favor of sustainable development and environmental quality (Jarvis, Varma, and Ram 2011).

Table 4
Indicators covered

Category	Indicator	Code	Measure
Socio-economic	Production		M.EUR
	Income (induced)		M.EUR
	Value added	VADDED	M.EUR
	Green jobs (thousands)	EMPLOY	By skills
			By sex
Environmental	Greenhouse gases emissions (Gigagrams CO_2eq)	EM_GHG	kg CO_2
			kg CH_4
			kg N_2O
	Water footprint (Mm^3)	WATERF	Mm^3 Water consumption blue
			Mm^3 Water consumption green
	Land use (km^2)	LAND_U	km^2 Cropland
			km^2 Forest area
			km^2 Permanent pastures
			km^2 Infrastructure land
			km^2 Other land use
	Material footprint (domestic extraction used in kt)	MAT_FP	kt Metal ores
			kt Non-metallic minerals
			kt Fossil fuels

Source: own elaboration

3.2. Cost data

As we are assessing changes in final demand in a long-term horizon (2018-2030), we assume that the productive structure pattern in Mexico has remained unchanged from 2011 onwards. REmap scenario and PRODESEN data provide different costs ($/kW) (see Table 2). This paper uses the latest data to assemble a final demand vector. Sectoral breakdown allocation is based on (Breitschopf, Nathani, and Resch 2012), with the exception of solar thermal, where data from (Rodríguez-Serrano et al. 2017) was used. To allocate the imported components in the construction of energy power plants we have identified the intermediate inputs in the construction sector in Mexico, differentiating between imported and domestic, and by measuring the shares by country and sectors, a final vector has been created for every measure of Table 1.

Data from PRODESEN has already applied the net present value to bring the investment and O&M costs to 2018 with a discount rate of 10% (SENER 2018a). An inflation rate of 30.55% has been calculated on the basis of the Producer Price Index provided by OECD data to bring PRODESEN values to the MRIOT 2011 current prices (OECD 2019). Then, an annual average exchange rate of 1.392 provided by the European Central Bank is used to convert dollars into euros and fit EXIOBASE requirements (ECB 2019). A final demand vector has been assembled for every energy technology proposed in both, PRODESEN and REmap case scenarios (see SI), where costs are broken down and assigned to different sectors based on detailed technical descriptions available (see Table 5). In the case of PRODESEN proposal, the 58.8% of the total investment is directly satisfied by the domestic market (11,040 M€), while according to IRENA, the participation of Mexico in satisfying its investments would be the 60.8% (35,775 M€).

Table 5.A

Final demand data for RES additional deployment in Mexico (M€, year 2011)

Region	PRODESEN			REmap 2030		
	Investment	O&M	Total	Investment	O&M	Total
MEX	10,824	216	11,040	35,160	615	35,775
USA	3,556	0	3,556	10,402	0	10,402
CHN	1,722	0	1,722	5,278	0	5,278
ROA	1,275	0	1,275	3,771	0	3,771
EUR	718	0	718	2,153	0	2,153
ROW	463	0	463	1,391	0	1,391

Source: own elaboration.

Table 5.B

Sectoral breakdown of RES additional deployment in Mexico (M€, year 2011)

Sector	PRODESEN			REmap 2030		
	Investment	O&M	Total	Investment	O&M	Total
Electrical and Optical equipment	5,598	25	5,622	15,149	72	15,221
Machinery, Nec	4,153	78	4,231	14,148	207	14,355
F.-Construction	4,397	10	4,406	13,944	49	13,993
Mbasic Metals and Fabricated metals	705	11	716	5,372	30	5,402
Chemicals and chemical products	1,085	1	1,086	3,096	2	3,098
Renting of M&Eq and other business activities	843	14	856	2,325	30	2,356
Rubber and plastics	965	0	965	1,879	0	1,879
G.- Wholesale trade except of motor vehicles and motorcycles	541	0	541	1,544	0	1,544
H.- Land transport services	235	0	235	514	0	514
O - Public administration and defence; compulsory social security	35	0	35	177	0	177
A.- Agriculture, forestry and fishing	0	59	59	0	176	176
K - Financial intermediation	0	8	9	1	19	20
Production of electricity by wind	0	8	8	0	15	15
Other community, social and personal services	0	3	3	0	12	12
Other Non-metallic mineral	2	0	2	7	0	7
Coke, Refined petroleum and nuclear fuel	0	1	1	0	2	2

Source: own elaboration

4. Preliminary results

4.1. Triple Bottom Line assessment of Green investments in Mexico

According to PRODESEN and IRENA's packages on RES deployment, these green investments are expected to account for the 2.2% and 7% of GDP in Mexico (year 2011 prices), respectively. Since IRENA's Roadmap, consistent with the Paris Agreement goals, is a more ambitious package than PRODESEN (see Table 5), the higher investments translate into higher socioeconomic and environmental impacts (Table 6). The impacts can be assessed from two points of view: the production-based accounting perspective (PBA) that considers the origin-country of the impacts considered, and the consumption-based accounting (CBA) that accounts the destination-country of the impacts. When focusing on the environment, the CBA is the footprint. Thus, the value added created by IRENA's investments inside Mexico is 26,857 M.EUR, while 58,771 M.EUR refers to the total value added created in the world as a result of deploying IRENA's package in Mexico, the destination-country of the investment.

Table 6

TBL impacts of RES deployment in Mexico

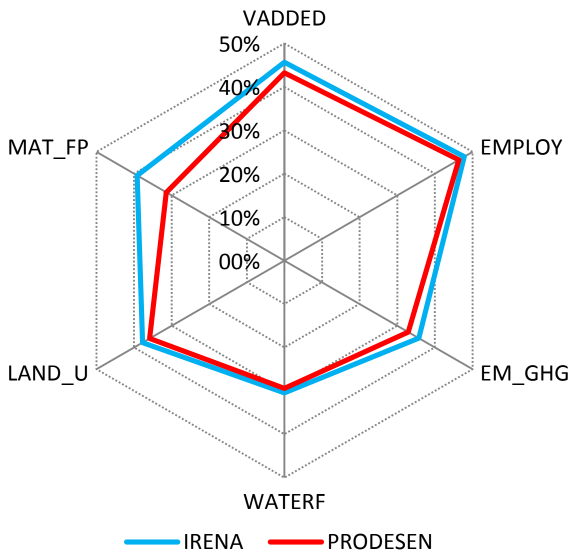
		IRENA		PRODESEN	
Indicator	Unit	PBA	CBA	PBA	CBA
VADDED	M.EUR	26,857	58,771	8,111	18,775
EMPLOY	1000p	1,347	2,816	423	911
EM_GHG	$GgCO_2$	16,839	47,080	4,899	14,889
WATERF	Mm^3	670	2,199	221	751
LAND_U	km^2	6,852	18,158	2,214	6,182
MAT_FP	kt	19,491	49,754	4,439	14,145

Source: own elaboration

In this sense, IRENA's proposal boosts domestic content (PBA) more than PRODESEN in all the indicators proposed for the Mexican economy. That could be explained by the differences in RES deployment structure, where technologies such as Hydropower (16.8% of total MW installed proposed by IRENA against 6.4% proposed by PRODESEN) are more likely to boost national economy in terms of domestic value added and job creation. In terms of employment, 1.35 M jobs would be created under IRENA's proposal in Mexico (both directly and indirectly). According to PRODESEN budget, 0.42 M jobs would be created. Domestic content in environmental indicators are also higher. Despite socioeconomic indicators, higher domestic content in environmental indicators mean that the weight of the different RES technologies proposed by IRENA make this scenario less environmentally friendly. This phenomenon is seen mostly in the material footprint.

Figure 1

Domestic factor content on Green investments in Mexico (in percentages)

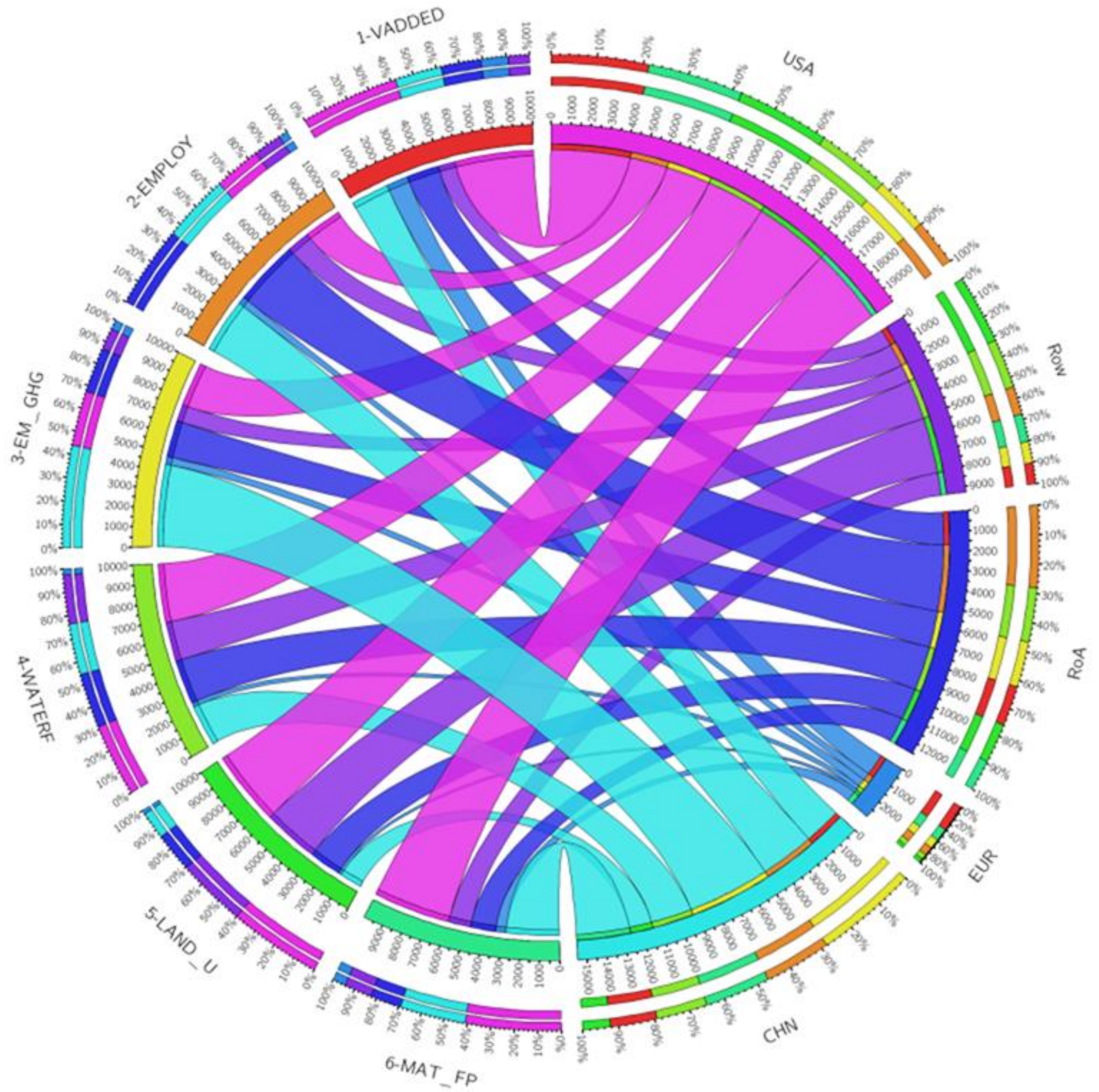


Source: own elaboration

When measuring the environmental footprints (CBA), PRODESEN, would have a carbon footprint of 14,889 $GgCO_2eq$ emissions, a water footprint of 750.95 Mm^3, a land footprint of 6,181.8 km^2 and a material footprint of 14,145.2 kt. The more ambitious proposal of IRENA's investments would create estimated emissions of 47,080.1 $GgCO_2eq$ (only 36% are domestic), 2,198.8 Mm^3 of water consumption (39%), 18,158.1 km^2 of land use (36%) and 49,753.9 kt of materials (30%). More than the half of the environmental footprints are explained by imported content. This can be understood here in terms of responsibility as a leakage, since Mexico's consumption of imported content embodies GHG emissions, water, land use and materials

(QUOTE). The main origin-countries of these leakages depend on the indicator. Focusing on GHG emissions, that are the key indicator of this paper, it is China, followed by the United States and the Rest of Asia (Figure 2). Deploying RES in Mexico implies emitting GHG. However, the emissions embodied in imported content are not negligible, being China and the United States the origin of these emissions. These are the two most polluting countries and the latter one has announced his intend to withdraw from the Paris Agreement, with the possibility of leaving in November 2020. Since the United States is Mexico's major trading partner, this would affect the Mexican environmental footprint.

Figure 2
Triple Bottom Line imported content of IRENA's package (in percentages)



Source: own elaboration

4.2. Triple Bottom Line assessment of changes in the electricity mix

Assuming that both PRODESEN and IRENA's RES deployment is fulfilled in Mexico in 2011, a change in the electricity mix structure of EXIOBASE has been conducted to calculate the TBL net effects in the six indicators proposed in this study (see Table 7). Thus, BAU scenario is the one that took place in 2011 in Mexico. PRODESEN and IRENA's scenarios show how the Mexican economy would perform once the facilities proposed have been deployed. In these preliminary results, green investments in RES deployment by PRODESEN and IRENA are not considered.

Table 7

Production of electricity scenarios (in percentages)

GWh	2011 (BAU)	PRODESEN	IRENA
By coal	10,82%	7,07%	3,15%
By gas	57,72%	54,75%	44,90%
By nuclear	3,89%	6,46%	4,36%
By hydro	13,81%	8,62%	12,07%
By wind	0,04%	12,62%	15,34%
By petroleum and other oil derivatives	11,21%	1,70%	0,80%
By biomass and waste	0,00%	2,38%	2,51%
By solar photovoltaic	0,00%	4,00%	10,98%
By solar thermal	0,00%	0,01%	0,60%
By tide, wave, ocean	0,00%	0,00%	0,00%
By Geothermal	2,51%	2,40%	5,28%
Production of electricity nec	0,0%	0,0%	0,0%

Source: own elaboration on the basis of EXIOBASE, PRODESEN and IRENA

When assessing PBA, under PRODESEN scenario, higher values are shown in VADDED. This means that a mix with that participation of RES gets the higher GDP. Nonetheless, differences in value added are very small (67.8 M.EUR with respect to BAU and 27 with respect to IRENA). This is 0.008% and 0.003% of the Mexican GDP, respectively (see Table 8). IRENA's scenario is the best-case scenario in the rest of the indicators calculated. Under IRENA's scenario, 36,854 additional jobs are created when compared to BAU (4,192 compared to PRODESEN); 46,612 $GgCO_2eq$ emissions are avoided with respect to BAU (21,996 compared to PRODESEN); 4.51 Mm^3 of water consumption in the production process are avoided compared to BAU, and 4,282.8 kt of materials.

Table 8

Net effects of the change on the Mexican electricity mix (in percentages)

Scenario	Indicator	Unit	Domestic	Boost	Leakage	PBA	CBA	BAL
IRE vs BAU	VADDED	M.EUR	0.0139%	-0.0390%	-0.0436%	0.0049%	0.0035%	-0.0014%
	EMPLOY	1000p	0.0877%	0.0435%	-0.0077%	0.0791%	0.0720%	-0.0071%
	EM_GHG	GgCO2	-8.6342%	-4.9133%	-0.1356%	-7.8400%	-6.4129%	1.4270%
	WATERF	Mm3	-0.0056%	0.0004%	-0.0031%	-0.0039%	-0.0048%	-0.0009%
	LAND_U	km2	0.0000%	0.0000%	-0.0029%	0.0000%	-0.0008%	-0.0008%
	MAT_FP	kt	-0.9809%	-0.5680%	-0.1024%	-0.8778%	-0.6998%	0.1780%
PRO vs BAU	VADDED	M.EUR	0.0213%	-0.0560%	-0.0387%	0.0081%	0.0104%	0.0023%
	EMPLOY	1000p	0.0828%	0.0175%	-0.0088%	0.0701%	0.0678%	-0.0023%
	EM_GHG	GgCO2	-4.2368%	-3.7850%	-0.1166%	-4.1404%	-3.1599%	0.9805%
	WATERF	Mm3	-0.0005%	-0.0030%	0.0019%	-0.0012%	0.0002%	0.0014%
	LAND_U	km2	0.0008%	0.0000%	0.0014%	0.0006%	0.0010%	0.0004%
	MAT_FP	kt	-0.8392%	-0.4876%	-0.0810%	-0.7514%	-0.5966%	0.1548%
IRE vs PRO	VADDED	M.EUR	-0.0074%	0.0171%	-0.0049%	-0.0032%	-0.0070%	-0.0037%
	EMPLOY	1000p	0.0049%	0.0260%	0.0011%	0.0090%	0.0043%	-0.0047%
	EM_GHG	GgCO2	-4.5919%	-1.1727%	-0.0191%	-3.8594%	-3.3592%	0.5002%
	WATERF	Mm3	-0.0051%	0.0033%	-0.0050%	-0.0027%	-0.0050%	-0.0023%
	LAND_U	km2	-0.0008%	-0.0001%	-0.0043%	-0.0006%	-0.0018%	-0.0012%
	MAT_FP	kt	-0.1429%	-0.0808%	-0.0215%	-0.1274%	-0.1038%	0.0235%

Source: own elaboration

The major changes take place in terms of GHG emissions reductions. Under IRENA's proposal, the domestic emissions (produced in Mexico to satisfy domestic final demand) are reduced in 8.6% with respect to BAU. Emissions produced in Mexico to satisfy foreign final demand also decrease in 4.9%. This scenario also fosters emission reductions in imports. As a producer, Mexico's reductions are 7.84%, or 46.6MtCO_2eq. Under IRENA's scenario, the balance of emissions in Mexico as a net consumer of CO_2eq emissions increases in 6,010.5 Gg. PRODESEN proposal benefits Mexico in a lower extent, since reductions as a producer of CO_2eq emissions are a 4.14% with respect to BAU, that is, a 24.6MtCO_2eq.

Another important change is in employment. IRENA increases the employment in 0.079% with respect to BAU (both directly and indirectly). This might seem a small amount, but 36.85 thousand additional green jobs are estimated to be created under a scenario where Mexico is committed to achieve the Paris Agreement goals. That it, investing in RES deployment is not in benefit of the environment, but also creates job opportunities for Mexicans. Under PRODESEN policy package, consistent with Mexican INDC, job creation would reach 24.6 thousand additional green jobs. Under IRENA's scenario, employment creation is specially pushed by domestic final demand, followed by exporter employment. On the contrary, imported employment decreases. Under PRODESEN, only employment creation boosted by domestic final demand experiences a significant improvement.

The RES deployment also has an important impact on material domestic extraction used. Under IRENA's scenario 4,282.8 kt of material domestic extraction are avoided in Mexico. Besides, leakage of material extraction from abroad, consumed in Mexico, is also avoided (0.1024%). This means that IRENA's scenario has a lower impact on material depletion. This reduction might be driven by a shift into renewables, and the subsequent reduction in fossil fuels use. In the case of PRODESEN, 3,666.1 kt of material domestic extraction are avoided.

The only case where BAU has a better performance than IRENA and PRODESEN is in land use (km2). However, this reduction of 0.03km^2 with respect to IRENA, and 6.92km^2 with respect to PRODESEN is imperceptible.

5. Preliminary conclusions

As a preliminary conclusion, focusing on RES deployment, IRENA's proposal performs better in socioeconomic terms, creating more domestic value added and employment than PRODESEN. On the contrary, under the imported content assumption of this paper, the environmental indicators' performance is worse under the IRENA's scenario. Further analyses on the sectoral and technological issues would shed light into the reasons why IRENA underperforms PRODESEN in the environmental categories.

A change into a RES-intensive electricity mix in Mexico affects notoriously only in GgCO_2eq emissions reductions when IRENA and PRODESEN scenarios are assessed. Net effects on employment and GDP growth are also supported by RES deployment in Mexico. In a nutshell, green investments in Mexico are not only a way of accomplishing environmental, but also socio-economic goals.

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