Q9 # Do solar photovoltaic clean development mechanism projects contribute to sustainable development in Latin America? Prospects for the Paris Agreement

Q8 The corrections made in this section will be reviewed and approved by a journal production editor.

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## Abstract

Clean Development Mechanism (CDM) projects must include intended contributions to sustainable development in their scope, in addition to promoting the reduction of greenhouse gas emissions (GHG). Previous studies have identified expected co-benefits in CDM projects, nevertheless, they have not focused on solar photovoltaic energy. Although there is high solar irradiation in Latin American countries, there were only 25 registered solar photovoltaic CDM projects. In this study, we examine the intended co-benefits for sustainable development of solar photovoltaic CDM projects in Latin American countries and investigate the climate and energy policies that may have led to the low number of registrations for these projects in the region. The analysis was performed using the T-Lab software program through its Dictionary-Based Classification tool applied to the outlined indicators and criteria. The results indicate gaps in project contributions, for example, the technology transfer was mentioned as equipment and knowledge importation from other countries, which does not imply the development of the local solar industry; community engagement and equal gender opportunities continue to remain challenges, water quality and conservation of biodiversity issues were underscored, and the reducing the overuse competition between cropland and solar panel installation was overlooked. CDM was important to promote diversification in electricity generation in most Latin American countries, but not sufficient to improve the solar photovoltaic market. The main barriers to implementing these projects have been regulation and lack of incentives. The national energy and climate policies in the region should set guidelines/standards for assessing the co-benefits for the sustainable development of GHG reduction projects, aligned with the new carbon market mechanism rules and the UN-Agenda 2030.

**Keywords**:

Solar photovoltaic energy, Clean development mechanism projects, Co-benefits for sustainable development, Climate policy, Energy policy, Latin America

### Abbreviations

No keyword abbreviations are available

## Data availability

Date used in the sutudy is from an open source: UNEP website.

## 1 Introduction

Under the Kyoto Protocol, the Clean Development Mechanism (CDM) projects with the highest registration in the United Nations Framework Convention on Climate Change (UNFCCC) were those related to renewable energies. CDM played an important role in increasing the market share of renewable sources and investments in the diversification of energy sources. It contributed to energy transition plans since the role of renewable energies in reducing consumption and dependence on fossil fuels is recognized as essential for the transition toward a low-carbon society (Ghezloun et al., 2012; United Nations, 2015a; UNFCCC, 2012). Fossil fuels represent 80% of the total energy supply globally and electricity, and since heat generation from fossil fuels corresponds to over 40% of global $CO_2$, this indicates the role of renewables such as solar energy for the decarbonization contribution of the energy sector (REN21, 2020; IEA, 2021b).

According to article 12 of the Kyoto Protocol, CDM is a "two-track" instrument designed to achieve reductions in greenhouse gas (GHG) emissions, thus helping developed countries to achieve their quantified commitments, and on the other hand, promoting sustainable development in developing countries (Lazaro and Gremaud, 2017; Torvanger et al., 2013). However, CDM projects were criticized as a false solution for mitigating climate change because they legitimize the increase of GHG emissions by providing a cheap way for polluting countries to avoid taking serious action on climate change and make little contribution to achieving sustainable development (Benites-Lazaro and Mello-Théry, 2017; Torvanger et al., 2013; Bumpus and Liverman, 2008).

These criticisms reflect the contradictions of some climate change solutions which can bring negative externalities and perversities to both the environment and the communities around which these projects are implemented. As emphasized by Loloum et al. (2021), the energy transition concept itself involves ethical dilemmas, and it does not necessarily imply a political transition or transformation. These projects, whether they are fossil or renewable energies, follow colonial mentalities and dependence in many developing countries (Loloum et al., 2021). On the other hand, Lazaro et al. (2022) mention that most of the literature on the energy transition does not emphasize the reduction of energy demand and consumption is fundamental to a sustainable energy transition. The absence of such an argument in the energy debate can give a false perception that replacing consumption based on fossil fuels with renewable sources is adequate. These changes in the energy system are presented by the authors as a trend of "energy addition" or "energy diversification" rather than as an energy transition.

The energy sector plays a fundamental role in the search for solutions for both climate change mitigation and sustainable development. Mainly, Sustainable Development Goal (SDG) number 7 seeks to "guarantee access to affordable, reliable, sustainable and modern energy for all" (United Nations, 2015a). However, the challenges to achieve this goal are complex due to divergent economic development and resource availability, national energy strategies and different priorities to achieving the overall goals. Moreover, countries have not found a common definition of "sustainable energy", nor agreed on a convenient path to achieve it (United Nations, 2015b).

This same challenge was seen in evaluating the co-benefits for the sustainable development of CDM projects. This is partly due to the absence of an internationally accepted definition of sustainable development since it can vary from country to country according to the criteria of the host country, resulting in requirements and indicators which are not very objective and difficult to verify. There is even a mistaken understanding in some countries that sustainable development is synonymous with economic growth (Subbarao and Lloyd, 2011). Such is the case in Latin America where many countries viewed CDM projects as a way to attract investments and support economic development ( Lazaro and Gremaud, 2017).

Each CDM host country is free to set its own guidelines and requirements for assessing the co-benefits for the sustainable development of CDM projects, depending on each country's perceptions and needs. These standards are usually qualitative, so each CDM proponent is free to fill the Project Design Documents (PDDs) in their own way (Godoy et al., 2022). For example, this is evident when comparing Brazilian and Peruvian hydroelectric projects, indicating that the former's co-benefits regarding sustainable development are more subjective than the latter's (Cole and Roberts, 2011).

The literature shows that most studies (Olsen and Fenhann, 2008; Fernández et al., 2012; Karakosta et al., 2013) used the three dimensions of economic, social and environmental sustainability in the evaluation of co-benefits. The literature also shows that studies have based their analysis of intended co-benefits for sustainable development from evaluating the PDDs and focus on several types of projects (Benites-Lazaro and Andrade, 2019) such as small-scale renewable energy projects in rural communities (Subbarao and Lloyd, 2011), wind projects (Góes et al., 2021), and hydro and methane avoidance projects on local employment and income generation (Mori-Clement and Bednar-Friedl, 2019). Wang et al. (2013) indicated the high potential of solar PV energy projects in China to create indirect jobs when compared to other types of renewable sources since they require providers of installation services, and the development of the local solar sector may lead to implementing distributed energy systems. Simsek et al. (2019) studied the contributions of solar thermal power projects in Chile. Cui et al. (2020) evaluated the impacts of renewable energy and energy efficiency of CDM projects on firms' innovation in technological fields. Studies which have CDM projects in Latin America as target found that the projects present economic and environmental co-benefits for sustainable development (Lazaro and Gremaud, 2017) and emphasize that most projects had implemented corporate social responsibility activities aiming to achieve social acceptance (Benites-Lazaro and Mello-Théry, 2017). Viviescas et al. (2019) defend that the complementarity of renewable and clean energy sources – such as wind and solar in different countries of Latin America – has great potential to generate co-benefits by increasing electrical stability/energy security of the local grid, decreasing the dependence of fossil fuels and providing diversification of the power generation matrix of the region.

The development of CDM projects in the period from 2006 to July 2021 was a total of 7833 CDM projects registered worldwide, in which 31.6% were wind projects, 26.8% were hydropower projects, 8.3% were biomass energy projects, and solar photovoltaic (PV) projects represented only 4.9% (Fenhann and Schletz, 2022). Although previous studies on the CDM co-benefits can be found, they have not focused on solar photovoltaic energy co-benefits in Latin America (Góes et al., 2021; Simsek et al., 2019; Cui et al., 2020). A total of 1014 CDM projects were implemented in the region until July 2021, however, even with higher solar irradiation levels and the growth of the installed capacity of solar PV in Brazil and Chile, which reached 7.8 ~~-~~GW and 3.1 ~~-~~GW in 2020, respectively (IRENA, 2021a), there are only 25 solar PV CDM projects in Latin America.

Latin America is a region where hydropower, oil, and natural gas energy sources dominate (OLADE, 2019; ~~Rubio and d. M. Folchi, 2012~~Rubio and Folchi, 2012), and in the last years, the non-CDM solar energy market has been experiencing significant growth (IEA, 2021a). This fact draws attention to the importance of good governance between the CDM host countries' energy and climate policies for the effectiveness of the CDM instrument in boosting the renewables sources, and mainly how these instruments are promoting sustainable development and the just transition that ensures environmental sustainability as well as social inclusion, equality, poverty eradication, and decent work (Smith, 2017). Given this context, this study aims to analyze the intended co-benefits for sustainable development of solar CDM projects in Latin American countries and to investigate the climate and energy policy implications that led to the low number of registered solar CDM projects in the region. It also highlights the lessons learned that can provide insights for formulating new carbon market instruments under the Paris Agreement (Article 6) for the post2020 period.

## 2 Material and methods

The study designed a logical pathway with five steps: The first step was to build the profile of the solar PV CDM projects in Latin America by researching in the UNEP/DTU/CDM and IRENA databases: the number and capacity of solar PV CDM projects; the energy capacity of the total CDM projects and the installed capacity and production of solar PV in Latin America countries. The second step was to construct the corpus for the text analysis. The materials consist of 25 solar PV CDM Projects registered from 2005 to July 2021 for Latin American countries. The PDDs of these CDM projects are easy to access and download from the UNFCCC website (UNFCCC, 2022), and the consolidated data from the UNEP website (Fenhann and Schletz, 2022).

As described by Benites-Lazaro and Mello-Théry (2019) the PDD includes basic elements required to assess compliance with CDM requirements. The content of a PDD is mainly composed of seven sections: general description of project activity, baseline methodology, duration of the project activity/crediting period, monitoring methodology and plan, calculation of greenhouse gas emissions by sources, environmental impacts and other contributions, and stakeholder comments. For the purpose of this study, data were extracted from the following PDD sections: general description of the project activity, environmental impacts and other contributions, and stakeholder comments. These three sections provided a description of the proposed co-benefits for the sustainable development. It is important to point out that this article only analyzes the intended co-benefits for sustainable development of solar CDM projects *ex-ante* analysis. It is not verified whether these expected co-benefits were actually delivered by these projects *ex-post* analysis.

The selection of indicators to examine the intended co-benefits of solar PV CDM projects for sustainable development was the third step of this study. These indicators were chosen by an interactive process drawing from the confrontation of the information extracted (in the second step of the study) from PDD sections (general description of the project activity, environmental impacts and other contributions, and stakeholder comments) and the scientific literature review. The purpose of this process was to identify common indicators utilized by Latin American countries, since, as mentioned above, host countries are free to set their own guidelines/standards/regulations for assessing the co-benefits for the sustainable development of CDM projects. For example, these guidelines in Brazil are described in a document named "Annex III," which outlines the standards for evaluating the contribution of a CDM project to local sustainable development in terms of economic, social, and environmental improvements~~.~~ (Godoy et al., 2022). The result of this is shown in Table 1, which presents nine indicators for the three dimensions of sustainable development: social, economic and environmental.

alt-text: Table 1

Source: Developed based on Olsen and Fenhann (2008), Subbarao and Lloyd (2011), Spalding-Fecher et al. (2012), UNFCCC (2012), Benites-Lazaro and Mello-Théry (2019), Costa-Júnior et al. (2013), Fernández et al. (2012), Karakosta et al. (2013), Lazaro and Gremaud (2017), Mori-Clement and Bednar-Friedl (2019), Cole and Roberts (2011) and solar PV CDM PDDs.

**Table 1**

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Framework for the assessment of co-benefits for sustainable development by solar PV CDM projects.

| Indicator | Description |
|---|---|
| Economic Co-benefits | |
| 1. Employment, job and income generation | Economic improvements for the population through: creation of new direct or indirect job opportunities or retention of jobs (labor/permanent positions) during the construction, operation, and management phases; income redistribution and poverty alleviation; financial benefits of the project for the local economy through the payment of taxes and/or improvement of the commercial activity (food, transport, hotel management); enhancement of local investment in tourism and tourist facilities; reduction of the dependence on foreign energy sources. |
| 2. Improvement to infrastructure | Creation of infrastructure (e.g., new transmission lines, substations, roads, and bridges, new connections to the grid) and improved service availability (e.g., health centers, schools and water availability); release of energy distribution to more isolated zones. |
| 3. Development and diffusion of technology | Development, use, improvement and/or diffusion of a new local or international technology, international technology transfer or development of an in-house innovative technology; importation of relevant technological knowledge in the solar energy sector from foreign countries; importation of the main equipment such as modules, inverters, and trackers; stimulation of the development of the solar power industry; knowledge and know-how transfer; creation of study/research centers to offer trainings on solar power. |
| **Environmental Co-benefits** | |
| 4. Conservation | Promoting comprehensive utilization and/or protection of the local biodiversity (ecological, fauna, flora, vegetation, habitats); avoiding deforestation; promoting reforestation. |

| | |
|---|---|
| and/or promotion of biodiversity in ecosystems | |
| 5.Water quality | Promoting comprehensive utilization and/or protection of the local water resources; avoiding water contamination; improving water quality. |
| 6. Land resources | Promoting comprehensive utilization and/or protection of the local soil resources; avoiding impacts on the landscape (erosion); improving soil quality and recovery; Agricultural land. |
| **Social Co-benefits** | |
| 7. Engagement of local population | Community or local/regional involvement in decision-making; stakeholders consultation (community representatives, associations, regional and municipal government entities, environmental agencies, institutions, representatives of universities and NOGs, and/or public in general) through informative panels, workshops, events and/or meetings; solicitation of comments and contributions from local stakeholders by surveys, mailing, email, telephone calls, advertisement in newspapers, and/or press notes; respect and consideration for the rights of local/indigenous people. |
| 8. Promotion of education and/or training | Facilitation of education, dissemination of information, training, research for the operation and maintenance of the plant; Improvement of quality workforce in the area by technical training and qualification in different areas; establishment of agreements with local colleges and universities to promote environmental education (renewable energy, climate change, CDM, mitigation of global warming) and development of capacity in renewable energy, especially solar photovoltaic installation and maintenance, and research in renewable energy technologies. |
| 9. Gender inclusion and/or improved equality | Enhancement of the position of women in society; women, are intentionally included in processes; women are hired; gender improved equality. |

Then, in the fourth step, we evaluated the PDDs in an *ex-ante* analysis by using the T-Lab software program through Q4 its Dictionary-Based Classification tool (~~Franco, 2020~~Lancia, 2021). This tool enables qualitatively and quantitatively classifying keywords from the constructed corpus and according to a set of categories established in Table 1. The data exploration uses contingency tables, with both indicators and results of the classification being represented by the number of occurrences of each keyword. These occurrences are quantities resulting from the computation of frequencies of a word that occurs within a corpus. Furthermore, the tool presents the elementary contexts of the keyword, thus enabling a qualitative analysis on co-benefits for sustainable development of solar PV CDM projects in Latin America.

Finally, in the fifth step, the literature on climate change and renewable energy policies was searched in order to discuss our results and examine the local climate and energy policy implications which led to the low number of this kind of CDM project in the region. Thus, this latter section sought to discuss the policies of CDM host countries to look for evidence of barriers and the existence of a national regulatory framework that encourages the implementation of PV projects.

# 3 Results

## 3.1 Profile

Table 2 shows the solar PV CDM projects registered by regions worldwide. Africa and Asia & Pacific regions registered one project each in 2006, resulting in a total of two projects in that year. The largest number of projects in this sector was registered in 2012, reaching a total of 252, compared to only 24 projects registered in 2011 and 19 projects in 2013. Registries of projects greatly declined in 2013, not only in solar energy but in all sectors. Benites-Lazaro et al. (2018) relates this trend to two main factors. First, the low price of certified emissions reduction credits (CERs) since the average price of secondary CERs peaked at around € 23.10/tCO2e in 2008 and fell below € 0.4/tCO2e in 2017. Secondly, due to the uncertainty in the negotiations under the UNFCCC for an agreement beyond the Kyoto Protocol.

alt-text: Table 2

Source: Based on Fenhann and Schletz (2022).

Table 2

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Solar PV CDM projects by year and total CDM projects by region (2006–2021).

| Years | Africa | Asia & Pacific | Latin America | Middle- East | Total |
|---|---|---|---|---|---|
| 2006 | 1 | 1 | | | **2** |
| 2008 | | 1 | | | **1** |
| 2009 | | 9 | | 1 | **10** |
| 2010 | | 9 | | | **9** |
| 2011 | | 21 | | 3 | **24** |
| 2012 | 5 | 225 | 16 | 6 | **252** |
| 2013 | | 18 | 1 | | **19** |
| 2014 | | 15 | | | **15** |
| 2015 | 1 | 5 | 1 | 1 | **8** |
| 2016 | 4 | 7 | | | **11** |
| 2017 | 1 | 9 | | | **10** |
| 2018 | 1 | 1 | | | **2** |
| 2019 | 6 | 6 | 4 | | **16** |
| 2021 | | | 3 | | **3** |
| **Solar PV CDM** | **19** | **327** | **25** | **11** | **382** |
| **CDM Total** | **223** | **6430** | **1014** | **93** | **7833** |

Latin American countries have registered PV CDM projects since 2012 (16 projects), which was the last year of the first commitment period of the Kyoto Protocol. Only one project was registered in 2013, one in 2015, 4 projects in 2019, and 3 projects until July 2021. Most projects (20) have less than 30 -MW of capacity. Crystalline silicon solar cells were preferred in PV power plants. One of the main characteristics of solar PV projects is that most analyzed projects were implemented in desert areas.

Table 3 shows the number of projects registered and the capacity of the solar PV and total CDM of each project registered in Latin American countries until 2021. It also shows the installed capacity in 2021 and the energy production of solar PV plants in 2019. There are only 25 CDM solar PV projects (2.5%) of 1014 CDM projects registered in the region. Chile stands out among the six countries with 14 solar PV projects, followed by Peru with five projects. The high potential for solar radiation of the Atacama Desert – a region located in northern Chile, southern Peru, northwest Argentina, and part of Bolivia – can be one of the reasons for the large concentration of solar PV projects in this region. Also, the Atacama Desert is the sunniest desert in the world, and therefore has greater comparative advantages for installing large solar energy projects because of this geographical proximity to the heavily energy-intensive mining industry which has the necessity to reduce its carbon footprint (Simsek et al., 2019; Grágeda et al., 2016).

alt-text: Table 3

Source: Based on Fenhann and Schletz (2022) and IRENA (2021a).

Table 3

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Number and capacity of solar PV CDM projects and energy capacity of the total CDM projects and installed capacity and production of solar PV in Latin America.

| Countries | Solar PV CDM Projects | Total CDM Projects | Capacity of Solar PV CDM Projects (MW) | Energy Capacity of Total CDM Projects (MW) | Installed Capacity of Solar PV (MW) in 2020 | Solar PV Energy Production (GWh) in 2019 |
|---|---|---|---|---|---|---|
| Argentina | 2 | 46 | 20.0 | 1082.53 | 761 | 801 |
| Brazil | 1 | 344 | 3.0 | 17,761.32 | 7879 | 6665 |
| Chile | 14 | 110 | 604.2 | 3454.11 | 3106 | 6419 |
| Dominican Republic | 2 | 14 | 111.5 | 507.57 | 267 | 360 |
| Ecuador | 1 | 33 | 50.0 | 1451.87 | 28 | 38 |
| Peru | 5 | 61 | 96.0 | 3036.95 | 331 | 823 |
| **Latin America** | **25** | **1014** | **884.7** | **36,994.66** | **14,964[a]** | **19,031[a]** |

Note: (a) South America, Central America and the Caribbean.

Chile and Brazil accounted for almost 70% of all solar PV energy production in 2019 (EPE, 2020). Although Brazil has more than double of the installed capacity of solar PV of Chile, the country only has one solar PV CDM project registered due to the high costs and lack of government incentives for the sector (EPE, 2020; Souza and Cavalcante, 2016).

## 3.2 Intended co-benefits for sustainable development of solar PV CDM projects in Latin America

Fig. 1 shows the intended co-benefits for sustainable development of solar PV CDM projects in Latin American countries. The economic dimension presents the largest percentages. The employment dimension (related to the creation of jobs) is the most visible and immediate co-benefit for the local communities mentioned by the project proponents (36.2%), followed by technology (14.8%), and infrastructure (8.8%). The land and water indicators are highlighted in the environmental dimension (6.6% and 5.6%, respectively). The education indicator has the highest percentage in the social dimension (13.2%).

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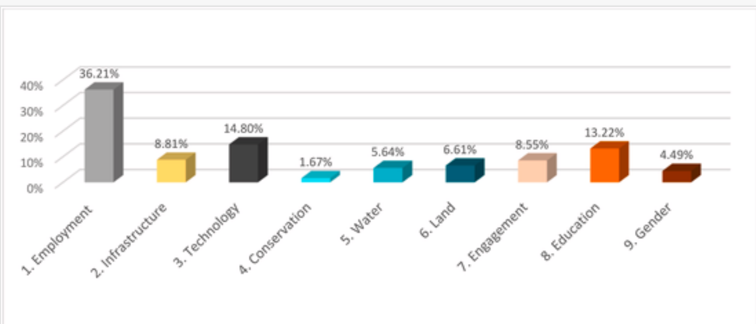
alt-text: Fig. 1

**Fig. 1**



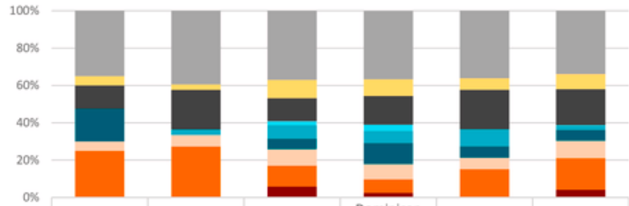

Intended co-benefits for the sustainable development of solar PV CDM projects in Latin America.

Fig. 2 shows the intended co-benefits for the sustainable development of solar PV CDM projects by Latin American countries. Projects in Chile, Dominican Republic and Peru described expected co-benefits for all the analyzed indicators. “Land resources” were not mentioned in the Brazilian project, and the “conservation and/or promotion of biodiversity in ecosystems” and “gender inclusive and/or improved equality” did not appear in the projects of Argentina, Brazil, and Ecuador. Furthermore, the “water quality” is hardly described in Argentina's projects.



alt-text: Fig. 2

**Fig. 2**




| | Argentina | Brazil | Chile | Dominican Republic | Ecuador | Peru |
|---|---|---|---|---|---|---|
| 1. Employment | 35.0% | 39.4% | 37.0% | 36.6% | 36.4% | 33.9% |
| 2. Infrastructure | 5.0% | 3.0% | 9.8% | 8.9% | 6.1% | 8.1% |
| 3. Technology | 12.5% | 21.2% | 12.3% | 15.4% | 21.2% | 19.2% |
| 4. Conservation | | | 2.2% | 3.3% | | 0.4% |
| 5. Water | | 3.0% | 7.2% | 6.5% | 9.1% | 2.2% |
| 6. Land | 17.5% | | 5.7% | 11.4% | 6.1% | 5.9% |
| 7. Engagement | 5.0% | 6.1% | 8.8% | 8.1% | 6.1% | 9.2% |
| 8. Education | 25.0% | 27.3% | 11.2% | 7.3% | 15.2% | 17.0% |
| 9. Gender | | | 5.8% | 2.4% | | 4.1% |

Intended co-benefits for the sustainable development of solar PV CDM projects by Latin American countries.

# 4 Discussion

## 4.1 Economic co-benefits

Fig. 1 shows “the employment/job creation” as one of the expected co-benefits that most solar PV CDM project developers described as a significant contribution to the sustainable development of the local communities (36.2%). A predominance of the economic indicator was also found in previous studies (for example, Fernández et al., 2012; Góes et al., 2018; Lazaro and Gremaud, 2017; Subbarao and Lloyd, 2011; UNFCCC, 2012; Du and Takeuchi, 2019). However, this result needs to be questioned because most CDM projects only described the creation of new employment/job opportunities mainly during the construction phase. Just a few of these job opportunities created in the construction phase are maintained throughout the lifetime of the projects due to the low demand for labor in the operation and maintenance phase (Góes et al., 2021).

Regarding technology, the second highest indicator in the economic dimension (14.8%), the Intergovernmental Panel on Climate Change (IPCC) defines technology transfer "as a broad set of processes covering the flows of know-how, experience, and equipment for mitigating and adapting to climate change" (IPCC, 2000, p. 3). The analyzed solar PV CDM projects state that technology transfer occurs when a link is established between the national and international industries for generating technology and knowledge transfer. This "transfer" uses training for staff to operate imported technology, which some call "transfer of capacities" by offering better job opportunities. This may indicate that the technology transfer rate for new projects in those countries has been significantly reduced, or that such transfer never existed. The project grid-connected electricity generation from a renewable source: Sete Lagoas Solar Power Plant in Minas Gerais-Brazil is a good example of this aspect, which describes: "*In relation to the technology to be employed in the project activity, it's important to emphasize that no technology transfer is previewed for the present project activity; nevertheless, know-how development and transfer is one of the main objectives of the R&D project activity, since one of the project's activity purposes is to investigate the performance of solar modules (losses), inverters, transformers, and other elements of photovoltaic systems under the typical environmental conditions of Brazil*" (UNFCCC, 2020 PDD 9056). The Atacama Solar PV Power Plant in Chile also informs that *"the technology to be installed is not a Chilean technology, however it is well established in projects worldwide"* (UNFCCC, 2020 PDD 9311).

A previous study showed that CDM projects in China contribute to promote technology transfer, technology innovation, and development of the renewable industry in the country (Cui et al., 2020). However, the technology transfer in the solar PV CDM projects in Latin American countries occurs by importing equipment from foreign countries, such as China and Spain. ~~(Werner, 2020).~~ Lower middle-income countries commonly import solar PV equipment for CDM projects (Lema and Lema, 2016). For example, the CDM projects in Brazil have not encouraged the development of cleaner technologies through cooperation among developed and developing countries (Costa-Júnior et al., 2013). Thus, technology transfer still has gaps which need to be overcome to benefit Latin American countries. Technology transfer should encompass incentives for innovation and national technological development. Similar to other renewable sectors such as the wind industry, companies based in Asia, mainly in China, control the solar PV industry and technology.

Despite not directly contributing to establish the PV technology industry in the countries, the solar PV CDM projects introduced this kind of renewable energy in the local market. A Solar PV CDM project in Chile mention that the project *"serves as a demonstration for wider application of solar power technology and other projects for clean renewable electricity generation in local and national level"* (UNFCCC, 2020 PDD 9248) and *"entails the import of expertise and experts in solar energy sector from foreign countries and accelerates the global sharing of relevant technological knowledge"* (UNFCCC, 2020 PDD 10542). A solar PV project in Dominican Republic states that the introduction of state-of-the-art of PV technology brings "*to the region new knowledge and experience that will benefit local workers through the labor specialization"* (UNFCCC, 2020 PDD 7781).

Regarding infrastructure, the third most scored indicator in the economic dimension (8.8%), most solar PV CDM projects described the construction of a grid-connected system, the transmission line to supply electricity to the national interconnected electric system. This infrastructure was necessary to develop solar energy projects since most of them were implemented in regions which do not have the infrastructure for energy generation. For example, the same solar PV project in Dominican Republic informed that the project *"contributes to improve the current situation, satisfying the growing demand for electricity and making possible releasing energy distribution to more isolated zones"* (UNFCCC, 2020 PDD 7781).

The study by Benites-Lazaro and Mello-Théry (2017) highlighted that there is a lack of large investments in infrastructure and public goods in Latin America, as insufficient, inefficient, and unsustainable provision of services characterize barriers for reaching sustainable development in Latin American countries. Thus, improvements made by the private sector through CDM projects can relieve several problems of lack of access to these basic services.

## 4.2 Social co-benefits

"Promotion of education and/or training" indicator was the first scored social co-benefit (13.22%). It was mentioned by solar PV CDM projects concerning the promotion of training local workers for operating and maintaining the solar plants, in addition to the good opportunity of providing environmental education, especially to the local children. A solar farm project in Chile points out the "*special professional training for local workers in the project and for householders in solar power household applications*" (UNFCCC, 2020 PDD 8760), and a solar PV project in Ecuador reveals the establishment of a study center for solar energy to be dedicated to technical training on solar power (thermal and photovoltaic) (UNFCCC, 2020 PDD 9511). A solar PV project in Chile highlights the partnership with local colleges and universities *"to develop capacity in renewable energy, especially solar photovoltaic installation and maintenance"* (UNFCCC, 2020 PDD 9311).

Regarding the "engagement of the local population", the second scored indicator (8.55%) in the social dimension was mentioned by all solar PV CDM projects. For example, Tacna Solar Photovoltaic Power Plant in Peru mentions that *"in order to inform the stakeholders about the construction and operation of the solar photovoltaic plant ... and its benefits for the community and its participation as a CDM project activity, the project developer voluntarily made a public consultation meeting"* (UNFCCC, 2020 PDD 5721). The stakeholder's participation is recognized by the UNFCCC in its Article 6, which urges all state parties to promote and facilitate public participation to address climate change. The stakeholder comments section is the basic element required in CDM projects. However, according to the Benites-Lazaro and Mello-Théry (2019), despite the stakeholder comments being mandatory, it is merely used by CDM developers as a rhetorical tool for legitimate company activities, but in practice, it provides almost no participation of the local communities. As mentioned in the Tacna Solar Photovoltaic PDD, the meetings for public consultation are carried out voluntarily by the developers. In many cases, only those stakeholders who are favorable to the project development participate in these consultations.

"Gender inclusion and/or improved equality" was the social co-benefit with the lowest percentage (4.49%). It did not appear in the projects of Argentina, Brazil, and Ecuador (see Figs. 1 and 2). There were few solar PV CDM projects that described this co-benefit. For example, the solar PV project in the Dominican Republic mentions the creation of "*new and permanent employment that would be available to anyone capable of doing the job, regardless of age, gender, race or culture and, thus, new jobs would stimulate equal opportunities for men and women*" (UNFCCC, 2020 PDD 7781). This mention can be criticized for the reason that climate change policies and projects have had low effects on gender relations, especially in developing countries. Gender issues have hardly been figured in the international policy discourse, including the Kyoto Protocol (Terry, 2009), the international post-2020 Kyoto Protocol agreement will have enormous implications for gender equality. This argument was also found in studies by Spalding-Fecher et al. (2012) and UNFCCC (2012), which show that equal gender treatment and opportunities continue to be a challenge in CDM projects.

### 4.3 Environmental co-benefits

Our results in Fig. 1 show that the "conservation and promotion of biodiversity in ecosystems" was the environmental co-benefit with the lowest percentage (1.67%). This co-benefit did not appear in the projects of Argentina, Brazil, and Ecuador (see Figs. 1 and 2). This result could be explained by the fact that many solar PV CDM projects have been implemented in desert areas. For instance, the Los Andes PV CDM Project describes that the project is located in the Atacama Desert with high homogeneity regarding landscape and lack of vegetation and wildlife. Also, the developers indicate that even though there are no conservative species, the project area is part of the guanacos' habitat, and there is the possibility of the existence of monuments, anthropological, and archaeological sites and bird species. There are likely implications to archaeological remains: "*As some Pre-Hispanic pottery remains were found within the Altos de Pica solar farm, its perimeter was modified in order to preserve them and to help archaeological research. The archaeological remains zone had been properly hurdled and signaled. In the same way, the layout of the high voltage line will be modified if archaeological remains or geoglyphs are found*" (UNFCCC, 2020 PDD 8760).

However, the construction of solar plants may cause biodiversity and ecosystem loss, microclimate disturbance, and landscape fragmentation (Chiabrando et al., 2009; Kabir et al., 2018). Furthermore, studies have shown that solar energy is energy-material-intensive and there is a lack of understanding of the risks of the direct and indirect consequences of mining activities on territories which are fundamentally important for the conservation of biodiversity and ecosystems (Knapp and Jester, 2001; Sonter et al., 2020). Although the solar panels have an expected life of around 25 years, several circumstances may reduce the modules' lifetime due to damage during transport and installation, irregular usage, lack of maintenance, water intrusion, exposure to dust, and heat damage. National policies and regulatory frameworks to incentivize recycling the end-of-life solar PV panels and the recycling chain are under development worldwide (Majewski et al., 2021). The recycling module process also presents problems, such as the discharge of pollutants into the environment (Xu et al., 2018). Then, the development of a recycling chain is essential for environmental protection to avoid dumping PV panels in landfills. Contrastingly, despite these negative impacts, some scholars defend that the implementation of solar PV plants in desert lands could offer gains because those lands correspond to one-third of the earth's surface (Dhar et al., 2020).

“Water quality” was the second scored social co-benefit (5.64%). This co-benefit did not appear in projects of Argentina (see Figs. 1 and 2). Most of the projects indicated that solar PV plants do not affect water quality. For example, the solar PV CDM project in the Dominican Republic describes *“photovoltaic energy is considered as the least polluting energy. As per the EIA conclusions, the impacts on the vegetation and habitats during the process of preparation and construction at the site will not be significant. During the operation stage, air emissions and water contamination are considered insignificant. Noise and the impacts on the landscape are also minimal during the operation stage”* (UNFCCC, 2020 PDD 7781).

Additionally, water consumption from aquifers was only reported for the developers during the construction phase and negligible during the operation and maintenance phase (UNFCCC, 2020 PDD 9311). However, studies indicate that the transition to renewable energies while maintaining the current levels of energy consumption has the potential to create new vulnerabilities and reinforce existing ones in terms of energy and food security, water and land competitive uses (Capellán-Pérez, et al., 2017; Benites-Lazaro et al., 2020).

The “land resources” domain was the environmental co-benefit with the highest percentage (6.6%). However, some important issues related to “land resources” are rarely discussed by the projects and this important co-benefit was not mentioned in the Brazilian solar PV CDM project. For example, the Monte Plata Project in the Dominican Republic states: *“There are no negative impacts on the underlying water deposits and the impacts on local bird species are minimal. The site where the project activity will be established was used mainly for agricultural activities; hence no relocation of local communities or individual households will take place and no forestation takes place”* (UNFCCC, 2020 PDD 8530). However, this example reveals a tradeoff of this project concerning food security due to competition with land use for agriculture.

Some studies showed increasing competition with land-use, land pressure and social impacts, and land tenure problems with communities in various countries, including cultivable land which is being earmarked for building solar energy projects (Dupraz et al., 2011; Späth, 2018; Lamhamedi and Vries, 2022; Hamed and Alshare, 2022). There is generally an absence of adequate spatial planning for the installation of solar or wind energy in Latin America, as large-scale solar farms may occupy spaces destined for agriculture, thereby conflicting with food production and the associated demand for land. Thus, spatial and energy planning should not be perceived as separate and distinct, but rather as a continuum of sectoral analyses leading to optimal solutions, and land conflicts are potential problems emerging from the push towards these projects (Lazaro et al., 2022). Thus, land use indicators should be considered in the energy and climate policies of host countries in Latin America to reduce the competitive use of agricultural land with cropland and managed forests, and the impacts of clearing land for construction and the placement of solar PV power plants on the habitats of native plants and animals needs to be evaluated.

### 4.4 Policies for renewable energy and climate change in Latin America

The commitments assumed by Latin American countries under the UNFCCC on climate change mitigation in the framework of the Paris Agreement have the promotion of greater use of renewable sources of energy and the increase of energy efficiency in common. Brazil established its intended Nationally Determined Contribution (iNDC) under the National Policy on Climate Change (Law no. 12,187/2009) to cut 43% of GHG emissions in 2030 by achieving 45% of renewables (wind, biomass, and solar) in the energy mix (Brazil, 2015). This country only has one solar PV CDM project, despite it being the leader in the number of registered CDM projects (344) in Latin America, mainly hydro (96), methane avoidance (65), wind (57), and biomass energy (48) (Fenhann and Schletz, 2022). Thus, the installed capacity of solar power plants in Brazil has been fast-growing since 2016 (IRENA, 2021a), but has not attracted the registration of solar PV CDM projects. Brazilian solar PV CDM projects represent only 0.04% of the installed capacity of solar PV plants and 0.02% of the energy capacity of total CDM projects (see Table 3).

Although the Brazil has potential for solar PV energy generation, the sector is still in progress and depends on the learning process, technological and economic incentives, and the creation of specific policies to promote PV energy ( Carstens and dos S. Cunha, 2019; Cunha et al., 2021a, 2021b, 2021a). Beyond CDM problems, considered by entrepreneurs as a bureaucratic, expensive, time-consuming instrument (Costa-Júnior et al., 2013), the reasons for the irrelevant market share of solar PV CDM projects in Brazil can be: a) the high cost of solar energy among renewable energies due to its exclusion of the PROINFRA – a governmental program to promote alternative sources of electricity; b) the lack of a PV industry in the country; and c) the decrease of energy auctions by the Brazilian government to obtain electricity from solar generation (Souza and Cavalcante, 2016; EPE, 2020).

Ecuador's iNDC aims to restructure the energy matrix focusing on the development of renewable sources, mainly sourced from hydropower (Ecuador, 2015). The government of Ecuador established the National Plan for Good Living 2013–2022 to reach 60% renewable energy generation capacity by 2017 through hydropower, the solar, wind, and other non-conventional renewables (IRENA, 2015). From 2000 to 2015, Ecuador had a feed-in tariff system to support renewable electricity, but in 2013 the regulation did not support solar PV under it (IRENA, 2015). The renewable electricity capacity generation represented 61% (59% from hydropower) in Ecuador in 2020 (IRENA, 2021b). This country currently occupies last place in terms of the installed capacity of solar PV energy in Latin America. The low attention to solar energy in the country may explain why Ecuador has just one solar PV CDM project (see Table 3). The major barriers to the development of the solar PV technology market in Ecuador are its high investment costs and the topographical and meteorological conditions of the country (Cevallos-Sierra and Ramos-Martin, 2018).

The island nation of the Dominican Republic is dependent on fossil fuel imports. It established Law no. 57-07 in 2007 to encourage the development of renewable energy sources, and the use of 25% renewable power by 2025 (Guerrero-Liquet et al., 2016). This country has abundant solar resources and expects to reach in 2030 a PV total installed capacity of 1.7 GW (IRENA, 2016). Solar PV CDM projects generated 111.5 MW in 2020, and represented 22% of the total renewable energy generation capacity of all CDM projects in the Dominican Republic (see Table 3). The solar PV sector faces barriers due to the lack of an appropriate national institutional and regulatory framework, as well as the high cost of investments needed to integrate renewables (IRENA, 2021a).

Argentina's iNDC includes the reduction of GHG emissions by 15% until 2030 by promoting (among other measures) larger participation in renewable sources (Argentina, 2015). The Argentinian Government launched the Law no. 27,191 in 2015 with a target of 20% of renewable energy (waves, solar, and biofuels) consumption by 2025 and a reduction of the use of thermal generation which reached 62% of electricity generation in 2017 (Schaube et al., 2018). One of the initiatives to develop the renewable energy sector was the RenovAr Program which started with an auction for wind, solar, biomass, biogas, and small dams (Schaube et al., 2018). Argentinian Law no. 27,424 in 2017 allowed residential users to become users/generators of solar photovoltaic energy (Coria et al., 2019; Sarmiento et al., 2019).

Argentina has found it difficult to attract international investment due to successive economic crisis (Haselip and Potter, 2010). This may be one of the reasons why Argentina has only two registered solar PV CDM projects. Argentina and Brazil were the Latin American countries with least penetration of solar PV CDM. This kind of project represented only 1.85% and 0.02%, respectively, of the total renewable energy generation capacity of all CDM projects in 2020 (see Table 3). Argentina is struggling to incentivize the PV market, even with large parts of the desert with good conditions for solar energy generation.

Peru's iNDC aims to promote renewable energy sources, which has given place to connecting wind farms, solar, and biomass power plants to the national grid (Peru, 2015). Peru started to increase investments in renewable energy (Legislative Decree no. 1002) in order to improve social inclusion and environmental care by establishing a policy for the sector to raise the rural electrification rate; as a result, a tender for 500,000 solar PV systems for rural electrification was announced in 2013, as well as an auction for renewable power from solar sources (IRENA, 2014; Lucas et al., 2020). In addition to the rural electrification plan, the improvements of the PV market in Peru are due to the promotion of large grid-connected PV systems in the desert lands in the south of the country. The implementation of small-medium size PV systems connected to the grid is still a missing gap because of barriers related to the national regulatory framework (Espinoza et al., 2019). The five small solar PV CDM projects of Peru represented only 3.16% of the total renewable energy generation capacity of all CDM projects in 2020 (see Table 3).

On the other hand, Chile addressed an incentive for Non-conventional Renewable Energies (NCRE). According to Law no. 20698, 20% of the energy must be generated from NCRE by 2025 (Chile, 2015a). The country created the Energy Security Plan and the Energetic Policy after a deep reflection as a consequence of the strong energy crisis that Chile has faced since 2004. This crisis is explained by the strong reductions in Argentine gas imports – over 90% of the contracted gas volume - due to supply cuts. This energy shortage was exacerbated by increases in the price of oil and by drought conditions (Chile, 2015b). The country presents high irradiation levels for solar energy in desert areas and favorable market conditions for new investors (Gil et al., 2020). Furthermore, there are heavily energy-intensive mining activities in the desert areas of the north of the country (Simsek et al., 2019). The mining industry is responsible for one-third of total consumption in Chile and large-scale companies in the sector have an environmental commitment to reduce their carbon footprint (Grágeda et al., 2016). Chile was the country with the largest number (14) of solar PV CDM projects in Latin America in 2020. Despite this, they only generated 17.5% of the total renewable energy capacity of all CDM projects in the territory (see Table 3).

As seen above, Latin America has great potential for solar PV energy generation; however, it still has a low level of solar PV energy production and the CDM was irrelevant to change this reality. Solar PV CDM projects represented only 6% of the 15 GW of solar PV installed capacity and only 2.39% of the 37 GW of energy capacity of total CDM projects in 2020 (see Table 3). Although CDM has introduced the use of solar PV energy in Dominican Republic and Ecuador, in Brazil and Chile (the Latin American leaders in solar PV installed capacity), the solar PV sector grew outside the scope of the CDM.

Effective renewable energy and climate policies, specific regulations/laws and investments are necessary for countries in Latin America to comply with their iNDCs and enhance diversification in energy generation mix (Washburn and Pablo-Romero, 2019). Many of the barriers to successful solar PV projects are at the regulatory and policy levels. Climate and energy policies need to be effective and require institutionalization of regulatory frameworks which improve solar PV project implementation, as well as encourage the establishment of reliable financial procurement systems that create options for investors (Carstens and dos S. Cunha, 2019; Espinoza et al., 2019; Gil et al., 2020; IRENA, 2016).

# 5 Conclusion and policy implications

The results of this study demonstrated that the most visible, immediate, and expected economic co-benefit for the local communities by the solar PV CDM project in Latin America was the creation of job opportunities during the construction phase, followed by technology transfer through the acquisition of solar technologies, mainly from China and Spain, as well as knowledge sharing with the personnel involved in the projects. The intended co-benefits in the social dimension were limited to the training of local workers, illustrating that community engagement and equal gender opportunities continue to remain challenges for solar PV CDM projects in Latin America. Intended co-benefits regarding the environmental dimension were highlighted by water quality and conservation of biodiversity issues.

The social co-benefit related to gender inclusion and the environmental co-benefits regarding the conservation of biodiversity and ecosystems have hardly been described by the projects in Argentina, Brazil, and Ecuador. However, these projects describe the co-benefits expected to be achieved at the time of project operation. In most cases, they only reflect potential co-benefits, not "real and measured" ones. The CDM instrument has a limitation in verifying whether the expected co-benefits are actually achieved. As mentioned in the introduction section, each CDM host country is free to set its own guidelines for assessing the co-benefits for the sustainable development of CDM projects. These standards are usually qualitative, so each CDM proponent is free to fill the PDDs in their own way. There are no monitoring devices to both check and enforce the proposed co-benefits. One of the reasons could be the non-monetary value of the co-benefits for sustainable development of the CDM projects in the carbon market, which prioritizes the CERs.

The new market mechanism of the Paris Agreement, Article 6.4, has been discussed since the Paris Agreement was launched. Rules, modalities and procedures were established during COP26 in Glasgow that guide credit emission reducing activities for companies, as well as cooperative approaches between Parties in bilateral arrangements to transfer emission reduction, and a work program was adopted to support non-market approaches. In 2022, the COP27 in Egypt deferred a decision on removal activities and avoidance credits to next year and the issue of potential double counting of non-authorized emission reductions (ERs) remains in discussion (UNFCCC, 2022). A new mechanism should not only prioritize economic issues, but also be more emphatic in terms of norms/rules for verifying whether the GHG reduction projects contribute to sustainable development, without new transaction costs emerging. It is important to point out that the CDM was considered by entrepreneurs as a bureaucratic, expensive and time-consuming instrument.

Moreover, the low number (25 projects) and small installed capacity (884.7 MW) of solar PV CDM projects in Latin America compared to other renewable energy sources highlights the irrelevance of the CDM to PV and the crucial role of multilevel governance between the global and national energy and climate policies to boost this sector and promote local sustainable development. Although CDM was designed to play an important role for helping developed countries to reduce their emissions of GHG by investing in diversified energy sources in order to increase the market share of renewables and encourage sustainable development in developing countries, it was insignificant to improve the solar PV market in Latin American countries. The reasons for this can be the low price of CERs under the UNFCCC and indefiniteness in the Kyoto Protocol and Paris Agreement negotiations which may impact entrepreneurs' interest to register solar PV CDM projects in Latin American countries and trade their carbon credits (Benites-Lazaro et al., 2018 ).

The energy transition from traditional fossil fuel sources to renewable sources faces several barriers in Latin America countries, which had an impact on the development of CDM projects, especially solar PV energy, namely: i) Hydropower is predominant in the energy mix of many Latin American countries (OLADE, 2019; Viviescas et al., 2019). In addition, governments in many countries prioritize fossil fuels as the main energy source and the potential influence and competition of other markets are blocking solar energy projects from quick development (Kannan and Vakeesan, 2016); ii) Latin American countries have to implement frequency regulations and active power control to overcome stability problems (Gil et al., 2020); iii) None of the countries in the region dominates solar energy technology, being dependent on other countries which already have this technology, which in turn reproduces traditional dependence (Newell, 2019; Ugarteche and Leon, 2022); and iv) a lack of high investment in infrastructure in Latin America countries (Benites-Lazaro and Mello-Théry, 2017).

As limitations of this study, it is important to highlight that all the discussions were focused on *ex-ante* analysis and not on *ex-post* one. This means that it could not verify whether the declared co-benefits from the solar PV CDM projects (*ex-ante* analysis) were actually delivered by them (*ex-post* analysis). Then, it is essential that future studies explore the *ex-post* analysis of solar PV CDM projects, even though gathering data about it is challenging. Another drawback was that the research of climate and energy policies and guidelines/standards/regulations of CDM co-benefits for sustainable development in Latin American countries was exhaustive and some of them were reviewed. The CDM was a global policy instrument that presupposes good multilevel governance for its effectiveness. It is not effective alone, thus, it is crucial that future studies prospect the role of multilevel governance of solar PV projects to improve sustainable development in Latin America.

### 5.1 Recommendations for the sustainable development mechanism

The implementation of Article 6 of the Paris Agreement is under negotiation to formulate the rules of the new carbon market mechanism, the so-called sustainable development mechanism, which will replace the CDM. This study provides insights which can be useful for the successful implementation of this mechanism. PDDs include the intended co-benefits as a requirement to allow CDM projects to be registered and emit CERs. However, after the CDM project installation, there is no evaluation or measure of the "real" co-benefits from these projects during the operation phase. As PPDs are prepared by independent consultants contracted by entrepreneurs, they only include information on the UNFCCC approval, which does not encompass commitments to guarantee achievement of the expected co-benefits of the projects.

Our results indicated that the new carbon market mechanism must include guidelines for host countries to ensure the co-benefits for sustainable development. The UNFCCC can guide countries in audit projects to guarantee sustainable development. Local human development may involve partnerships with local universities, research centers, companies and local communities. Thus, the new mechanism should formulate rules to supervise projects, encourage transparency, and measure co-benefits, without increasing the transaction costs so much. It needs to implement a monitoring instrument of co-benefits for sustainable development, provide a clear definition of the indicators, methods, and procedures for the evaluation of the "real" co-benefits of GHG emission reduction projects, and establish clear and long-term rules that can guarantee both market security and legal and institutional security. Furthermore, a regulatory framework must define the legal nature of CERs in terms of their tax and credit implications, including fiscal incentive measures for project proponents. Therefore, it should include results-based finance and integration of sustainable development goals, human rights, transparency, and public consultation as core principles.

In short, it is expected that the new mechanism may provide incentives to maintain the development of projects to reduce GHG emissions and stimulate collaboration for climate change mitigation among local public and private entities, as well as foreign companies. This can stimulate the solar PV market, energy transition to renewable sources, and sustainable development in host countries.

### 5.2 Recommendations for Latin American energy and climate policy

Although the results revealed a high potential for solar energy generation, Latin America has few solar PV CDM projects. In addition to CDM issues, the host countries climate and energy policies have not contributed to attract more solar PV CDM projects and guarantee the improvement of PV CDM market and local sustainable development in Latin America.

Most Latin American countries face difficulties in increasing the participation of solar PV energy in the electricity generation mix in part because of the prioritization of fossil fuels as the main energy form/source, and as a source of financing for economic development. This fact draws attention to the importance of a good multilevel governance between the new global carbon market mechanism and host countries' energy and climate policies for improving the solar PV market and sustainable development in Latin America.

Solar PV energy can contribute to the development of the SDG 7 and can also allow host countries and entrepreneurs to access the green finance market, such as securities dedicated to the green bond market. However, this must involve social inclusion and participation. Thus, the national energy and climate policies need to set guidelines/standards for assessing the co-benefits for the sustainable development of GHG reduction projects, aligned with the new carbon market mechanism rules and the UN-Agenda 2030 SDGs.

## Q7 Uncited references

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## CRediT authorship contribution statement

**Janaina Ottonelli :** Conceptualization, Writing – original draft, Formal analysis, Writing – review & editing. **Lira Luz Benites Lazaro :** Conceptualization, Formal analysis, Formal analysis, ~~Writing – review & editing,~~ Software, Validation, Visualization, Writing - original draft. **José Célio Silveira Andrade :** Conceptualization, Writing – review & editing, Supervision. **Simone Abram :** ~~Writing – review & editing,~~ Conceptualization, Supervision, Writing - review & editing.

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# Highlights

- Employment opportunities are the main intended co-benefits of solar CDM projects.
- Technology transfer is understood as equipment importation.
- Regulation and lack of incentives discourage the implementation of solar CDM projects.
- New market instruments must ensure co-benefits, market security, and transparency.
- Climate and energy policies are required to stimulate renewable energy.

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