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Low Carbon Transition through Renewables Sources – An Overview of the Renewable Energy Program in the State of Minas Gerais

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ABSTRACT

The Renewable Energy Program of Minas Gerais is one of the initiatives which aims at the intensification in the use of renewable sources in the state. The present paper applies a methodology to evaluate the effectiveness of such instrument to expand the number of renewable energy projects and its contribution to achieve the goals of the energy sector of the Brazilian Nationally Determined Contributions, that is, to increase the use of renewable energy by 45% until 2030. It has been observed that the expansion of the renewable energy sources at regional level has advanced by incentive policies with clearly defined goals and guidelines. However, the analyzed program does not attend to all the requirements and it is possible to conclude that the main state public policy of renewable energy expansion did not accomplish its objectives suggesting that a balanced mix of public policies must be implemented in order to promote an effective energy transition.

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KEYWORDS

Renewable energy, Job creation, Climate change, Energy transition, Renewable energy program of Minas Gerais, Indicator measurements.

INTRODUCTION

There is an increasingly worldwide effort to make every action sustainable, and this is no different when it comes to energy issues. The way to conduct decision-making can deeply affect the economic, social and environmental aspects of a country. In this sense, energy plays a crucial role in providing the economic growth and sustainable development of a society. Anthropogenic actions, especially since the Second Industrial Revolution due to the large-scale use of fossil fuels, have contributed to the increase of the global average temperature and consequently to the climate change. The high availability of these resources and its low cost of exploration have led several countries to energy matrix based on fossil fuels. Taking the European countries and the United States as examples, the predominance of petroleum, coal and natural gas as the main sources of energy is evident, as it can be verified, for example in [1] and [2].

The use of fossil energy resulted in several undeniable benefits and concomitant with a major development of the world economy. However, the various negative issues associated with these resources have led to rethink the energy production technologies nowadays and the possible alternatives. In this way, several lines of study have investigated the role of the fossil fuels and the renewable fuels in different focus. For example, considering the possibility to substitute fossil fuel by biofuels in agriculture areas [3] and adopting the energy-economy-environment nexus in the models to estimate fossil fuel depletion and alternative energy expectations with the energy demand [4]. Another example of line of study performs comparison in relation to climate impacts if considering the use of forest residues or leave them in the forest and to use fossil fuels instead [5]. An interesting study demonstrates the substitution effect in renewable energy considering several countries of Europe highlighting the necessity for flexible and controllable electricity production from natural gas and hydropower and demonstrating that peaks of electricity have been an obstacle to the accommodation of intermittent renewable sources [6]. Some researches demonstrate also that with the implementation of energy savings, renewable energy and improving the conversion technologies it is possible to obtain optimistic results, for example, positive socio-economic effects and increase in employment creation [7].

The global warming is the most known impact caused by climate change and in the last 30 years the Earth's temperature has risen almost 0.2 K every 10 years [8]. Moreover, in the long term, fossil energy sources will be limited. In addition, in 2004, according to data presented by the Intergovernmental Panel on Climate Change (IPCC), about 56.6% of the global anthropogenic Greenhouse Gases (GHG) emissions originated from the combustion of fossil fuels [9].

In Brazil, in 2014, according to the World Resources Institute (WRI), that country ranked 7th in the world ranking of GHG emissions, which is headed by China and the United States. In 2014, 1,357 Gt of CO_2 equivalent (CO_2eq) were released, which corresponds to 2.8% of global emissions [10]. For the period between 1990 and 2014 gross Brazilian GHG emissions increased by about 14% [11].

In order to prevent the risks related to energy security and the challenges of climate change, the state of Minas Gerais embraced some measures aimed at the transition to a low carbon economy, driven mainly by ambitious national commitments, international agreements, and fast technological progress. Among these, the State Renewable Energy Program of Minas Gerais [(Programa Mineiro de Energia Renovável (PMER)], created by State Decree Number 46296 of August 14, 2013 [12], stands out as the main instrument for promoting renewable energy in the State. The PMER instruments and actions include benefits and incentives for the generation of centralized and decentralized electric power by solar, wind, biomass and hydroelectric sources, the latter generated in Hydropower Generation Centrals [(Centrais de Geração Hidrelétrica (CGH)] and Small Hydroelectric Plants [(Pequenas Centrais Hidrelétricas (PCH)]. Hydropower has a fundamental role in the energy matrix of the state of Minas Gerais. Data from the 31st Energy Balance of Minas Gerais state (BEEMG) [13] shows that hydropower was the fourth largest primary energy source demanded in the base year of 2015, with a contribution of 14.5%. However, the increasing reduction of hydropower capacity in the electricity sector due to altered hydrological regime can cause unfavorable changes to the energy matrix once the distribution system is interconnected, not only to the population of the region but to the country as well [14].

It is important to note that Brazil has established its Nationally-Determined Contributions (NDC) to achieve the Paris Agreement, signed at the 21st Conference of the Parties (COP-21) in Paris in December 2015, which aims to limit warming to well below 2 °C. Generally, cumulative emissions approaches are used to inform mitigation policy, but knowing what "2 °C" actually suggests is debatable [15].

With regard to renewable energy sources, the Brazilian NDC proposes that the country will reach an estimated 45% share of renewable sources in the energy matrix by 2030. It includes an expansion between 28% and 33% in the use of renewable sources, in addition to hydropower, in the total energy matrix by 2030 [16].

Usually, the process of analysing energy systems by using environmental indicators can bring new insights of sustainability. It is necessary to be able to measure the development level of a country, as well as to monitor the progress (or lack of it) towards sustainability [17]. However, this kind of evaluation is almost inexistent in the literature when it comes about analysing the effectiveness of specific policies to promote energy expansion not only in the economic and technical perspective, but also in the energy transition framework by using indicators such as carbon dioxide (CO_2) emissions [18]. Many times, is not clear exactly how many issues to consider and also how to relate to each other, and this can make the analyses quite complex. Moreover, there is not always a clear measurement to indicate whether or not the situation has improved with respect to any one issue [19]. It is very important to highlight that the procedures of sustainability have strong dependency on the local policies and several other relevant data, being priority to select all the basic indicators based on the sustainability definition and its assessment [20].

In this way, this study aims to contribute to the literature by combining an analysis of concepts and indicators that can measure the effectiveness of policies directed to accelerate energy systems transition. Interesting studies present actual past cases of energy transitions and factors behind them as, for example, the cases studied in Brazil and France [21] demonstrating that it is possible to transition between major energy sources within a few decades if the government recognizes a national need, but the transition success will depend also on several other aspects. It is necessary to think that the energy transitions follow a multidisciplinary nature and several factors lead to successful or unsuccessful models such as historical familiarity or the technological conductivity that are determinant for the change of the energy system [22]. Several past transitions were characterized as accidental or circumstantial, but future transitions can have social or political priorities with more planning and organization according to government objectives. Aspects such as scarcity, climate change, and innovation are considered fundamental drivers to accelerate future transitions [23]. Moreover, for a transition that considers a substantial penetration of renewable energy, it is essential to have an interconnected structure of the energy-environment-economic system [24]. The expansion of renewable sources such as wind, biomass and solar, which are spreading very quickly, is a key element in the ongoing sustainability transition of electricity, as for example, in China, United States, Germany and India [25].

Actually, to effectively implement the aims of the Brazilian NDC within the agreed period, coordinated efforts and the distribution of responsibilities among Brazilian states, the private sector and civil society are necessary to promote decentralized goals.

Therefore, this paper has as its main aim to evaluate the effectiveness of the PMER as the main instrument of the Minas Gerais Government to expand the number of renewable energy projects in the state, as well as their impact in achieving the goals for the Brazilian NDC energy sector. In this way, the results of several indicators are presented which are broadly accepted as effective tools to measure the capacity of public policies to act directly as a promoter of sustainable and low carbon economy. This study also aims to contribute to research on energy transition presenting the specific case of polices adopted in Minas Gerais.

The renewable energy program of Minas Gerais

As said before, the main aim of the PMER is to promote the expansion of electric power generation from renewable sources, excluding large hydropower plants. The program has a limited framework, since its actions are restricted exclusively to promote the generation of electricity using non-fossil sources. Thus, renewable fuels or renewable sources used directly for heating were not contemplated by the program.

It should be noted that the Decree that created the PMER does not discriminate specific conditions and instruments for Distributed Generation (DG). However, simultaneously with the construction of the program, incentives were discussed for the distributed micro and mini-generation that ended up being contemplated with specific tax incentives. In this way, it can be considered that DG is part of the PMER scope.

Due to strategic political interests to achieve the government goals in the energy sector set forth in the Government’s Multi-Year Plan of Action [26], PMER was created to be the main strategy of the State Government to attract investment, in order to expand the number of projects of power generation from renewable sources. The instruments contemplated in the Program Decree are [12]:

- Tax and tributary incentives;
- Partnership agreements for transmission lines through Public Private Partnerships (PPP);
- Priority in the solicitation and access to the system;
- Priority in environmental regularization processes;
- Priority in the formalization of energy purchase contracts;
- Specific funding line;
- Technical-scientific cooperation and training and qualification of human resources.

The goal of this article is to evaluate the effectiveness of the instruments that compose the Program in order to correlate them to the following indicators:

- Innovation;
- Number of implemented projects by the PMER;
- Creation of jobs;
- Mitigation of GHG;
- Costs associated with the Program.

INSTRUMENTS FOR INDICATORS MEASUREMENT

Each one of the instruments used in the analysis has been detailed. It can be concluded from the results that the renewable energy generation has increased in the last few years in the State. On the other hand, the analysis suggests that it is not possible to claim that the increase was due to the PMER, since it is not possible to discriminate the effects of its instruments from other possible conditions that may have led to the renewable energy expansion in the Minas Gerais energy matrix in the studied years.

Innovation

It is a great challenge for the current public administration to propose policies aligned with innovation criteria in order to improve the State's strategic role, and at the same time, the business environment enhancement and economic development. This should not be achieved only through traditional tools, but also with the introduction of modern methods that can add greater participation of society, transparency, speed and modernization of the tools of the public machine [27].

Government policies to create renewable energy markets must have mechanisms that facilitate the development of renewable technologies and promote cost reduction through economies of scale and technological gains. In this sense, the types of policies required differ according to national and local contexts. For the purpose of selecting the appropriate mechanism to develop policies aiming at the expansion of renewable energies, the International Renewable Energies Agency (IRENA) established the main instruments that should be considered in the construction of an effective policy, considering the context. These mechanisms are indicated in Table 1 [28]. The evaluation of the innovation indicators is being made based on the attendance of such mechanisms. In order to do that, each PMER instrument was categorized as national policy, regulatory instruments, fiscal incentives, grid access, and access to finance or socio-economic benefits in order to know if it attends the requisites to be considered as an innovative policy.

Table 1. Overview of the main types of instruments and measures adopted in renewable energy policies

National policy	Regulatory instruments	Fiscal incentives	Grid access	Finance access	Socio-economic benefits
Renewable energy target	Feed-in tariff	VAT/ fuel tax/income tax exemption	Transmission discount/exemption	Currency hedging	Renewable energy in rural access/cook stove programmes
Renewable energy law/strategy	Feed-in premium	Import/export fiscal benefit	Priority/dedicated transmission	Dedicated fund	Local content requirements
Technology-specific law/programme	Auction	National exemption of local taxes	Grid access	Eligible fund	Special environmental regulations
	Quota	Carbon tax	Preferential dispatch	Guarantees	Food and water nexus policy
	Certificate system	Accelaraed depreciation	Other grid benefits	Pre-investment support	Social requirements
	Net metering	Other fiscal benefits	-	Direct funding	-
	Mandate (e.g. blending mandate)	-	-	-	-
	Registry	-	-	-	-

Number of projects implemented by the program

To evaluate the results of the PMER in terms of the number of implemented projects, it is necessary to measure the range of the goal of the program by evaluating, at the State level, the electric power generation from renewable sources. In this sense, possible indicators for the analysis are listed, however, these are subject to criticism about their ability to capture the effectiveness of the program, its measurement failures, as well as possibilities to obtain data in a timely manner. In Table 2 are described the measurement instruments listed with their advantages and disadvantages.

After the data collection, graphics were made to analyse the expansion of the renewable energy in the state by evaluating the historical series of its growth. A graphic was also included comparing the distributed generation by renewable sources in the states of Brazil federation to correlate the advance on the matter of Minas Gerais state.

Table 2. The measurement instruments listed with their advantages and disadvantages

Measurement instrument	Renewable energy generation ventures in operation in Minas Gerais.	Renewable energy generation ventures with special tax regime at SEF/MG.	Renewable energy generation ventures with environmental license.	Production of electricity power by renewable source.	Distributed micro and mini-generation ventures installed.
Unit	MW or percentage (MW renewable energy/MW total energy).	Number of projects (possibility to use MW, according to information held by SEF-MG).	Number of developments (possibility to use MW)	Thousands of tons of oil equivalent (thousands toe)	It can be in MW, in number of ventures, in percentage of participation of Minas Gerais.
Data source	ANEEL *	SEF */MG	SEMAD *	BEEMG *	ANEEL
Advantages	It measures the expansion of renewable energy generation. The information is updated in greater than annual periodicity. It allows measuring the pace of the renewable energy capacity implantation growth in a given period.	It identifies the quantity of ventures that benefited from the special tributary regime granted to the renewable energy generation. If SEF has information about the electric power of the projects, it'd allow evaluating the installed power of ventures with special regime contemplated in the PMER.	It identifies exactly the quantity of ventures that obtained an environmental license, in any of its stages. It allows identifying ventures that were planned before and after the PMER, which may denote the influence of the Program.	It measures the increase of the renewable energy generated. It allows measuring the pace of renewable energy generation growth in a given period	It measures the expansion of DG in the State, in terms of ventures, installed capacity or position in relation to other federative units. It allows specification of renewable energy generation source. It is updated in greater than an annual periodicity.
Disadvantages	The indicator sums up the electric power capacity of all renewable energy generation ventures without differentiating those who actually benefited from any of PMER actions. It does not show the electricity actually generated by renewable sources, only the generation capacity installed.	Receiving the special tax regime does not mean that the venture is operating. The indicator does not allow knowing if the project was contemplated with any other benefit from the PMER. Difficulty in obtaining data from SEF.	Licensed ventures may not be installed. It does not allow knowing if it was contemplated with any other PMER's benefit. Difficulty in obtaining data from the SEMAD. It only presents information of installed power, not the amount of renewable energy actually produced.	Annual frequency with lag of 2 years.	It does not measure the energy actually generated, so it does not inform if the installed capacity is efficient or if it is working.

* ANEEL – National Electric Energy Agency (Agência Nacional de Energia Elétrica)
* BEEMG – Energy Balance of the Minas Gerais State (Balanço Energético do Estado de Minas Gerais)
* SEF – Secretary of State for Finance (Secretaria de Estado de Fazenda)
* SEMAD – Secretary of State for Environment and Sustainable Development (Secretaria de Estado de Meio Ambiente e Desenvolvimento Sustentável)

Creation of jobs

The International Renewable Energy Agency (IRENA) annually issues the number of jobs generated worldwide in the renewable energy market [28]. These reports, combined with data on the expansion of renewable sources in the world, allow generating an average number of jobs created per installed MW.

In Table 3, the aggregate data are shown for the first four years of the program, for the number of jobs and installed capacity in the world of sources contemplated in the PMER [29]. The ratio between generated jobs and installed capacity was calculated, and the result is an average data, since the selected factor is not individual for each source.

Once the average number of jobs created by MW was found, this ratio was applied to estimate the approximate number of jobs created in the state by the expansion of renewable sources in the energy matrix in the established period.

Table 3. Brazil's average number of jobs by MW of renewable source installed

Year	Generated jobs [10³]	Installed capacity [MW]	Average number of jobs by MW/year
2014	894	106.44	8.40
2015	934	112.62	8.29
2016	918	121.32	7.57
2017	876	128.29	6.83
Average number of jobs by MW: 7.77			

Mitigation of Greenhouse Gases

One of the objectives of PMER that can be reached by the expansion of renewable source is the mitigation of the GHG with a view to combating climate change, as well as transition to low carbon economy. In order to measure the results of the Program to achieve this objective, the GHG Emission Factors for the energy sector are provided by the Ministry of Science, Technology, Innovation and Communication [(Ministério de Ciência, Tecnologia, Inovações e Comunicações (MCTIC)], on an annual basis [30].

The Program insertion started from 2013, so the analyses are being performed in the first three full years of PMER, according to the average annual factors of Table 4 [30].

Table 4. Average annual factor

Year	Average annual factor [t CO_2/MWh]
2014	0.1355
2015	0.1244
2016	0.0817
2017	0.0927

Multiplying the average annual emission factor by the amount of MWh generated by renewable sources in the established period, it is possible to obtain the saved emissions, as it is being presented in the next section.

The emission factors provided by MCTI are based on the types of primary source of the Brazilian electric matrix, and the values are attributed mainly due to the presence of fossil fuels. As the program addresses the generation of electricity through renewable sources, the emission factor for these are being considered as zero during its operation phase, and the technology lifecycles will not be considered.

Thus, the result is based on the GHG emissions that were mitigated by the sector when using renewable energy instead of sources with fixed emissions.

Costs associated with the program

The main cost associated with the PMER for Minas Gerais is the instrument of tax incentives and differential tax treatment in the phases of construction and operation of the ventures originating from renewable energy for electric generation.

Currently, when it comes to incentives, the state government has regulated only the exemption from the Tax on Circulation of Goods and Services [Imposto Sobre Circulação de Mercadorias e Serviços (ICMS)] related to the types of ventures that are the scope of the Program. The data on income and expenses are processed by the State Secretary of Finance of Minas Gerais [Secretaria de Estado de Fazenda de Minas Gerais (SEF-MG)], which is responsible for analysing and publicizing the impact of PMER's benefits on the financial performance of the state.

Once this data becomes public, it is possible to determine the main costs of the PMER for the state government.

RESULTS

The five measurement instruments were selected to carry out the PMER impact analysis on the expansion of the number of renewable energy projects in the state of Minas Gerais associated with the Program, as previously mentioned in Table 2. However, although the instruments demonstrate efficiency in the measurement of the PMER results, instruments 2 and 3 do not have enough data available to perform the analysis.

Number of ventures implemented by program

Regarding the instrument 4, related to the BEEMG data, it is assumed that the information published in the last report refers to the period until 2014, so it is understood that these data are not yet capable of reflecting the PMER effects on the Minas Gerais ventures, and it is necessary to await the publication of more recent reports [31].

In this way, in this paper are presented the results of the instruments for which it was possible to obtain timely data (1 and 5). A more in-depth analysis of the numbers found in ANEEL's Generation Information Bank databases is also performed [32].

The total generation capacity installed by source, in Minas Gerais, from 2010 to 2016 is shown in Table 5 [32]. The ventures analysed were Hydro Power Plant (HPP), Small Hydroelectric Plants (SHP), Hydropower Generation Center (HGC), Wind Generation Plant (WGP), Photovoltaic Solar Plant (PVP), Distributed Generation (DG), and Thermoelectric Plant (THP). The data allows to verify the expansion of the capacity of each renewable source encouraged before and after the PMER, since it covers three years before and three years after the implementation of the Program and discriminates between renewable sources, including large and small hydroelectric. In the case of renewable thermals, the majority (around 80%) corresponds to the generation by means of sugarcane bagasse, but there are also plants that use biogas from urban and agricultural residues, black liquor, charcoal, blast furnace gas resulting from the use of biomass and wood residues.

The total installed generation capacity from 2010 to 2017 continued to grow, with an increase of 1,550.34 MW more at the end of the period compared to 2010. Regarding the sources addressed in the program, the photovoltaic is the one with the highest increase between the period of 2013 and 2017. However, from the launch of the PMER, the entry of new installed power from the other renewable sources presented a slow pace when compared with the photovoltaic, as shown in the Figure 1.

Table 5. Total installed generation capacity in Minas Gerais by source, 2010-2017

Year	Generation capacity [MW]								
	Source								
	HPP	SHP	HGC	WGP	PVP	THP renewable	THP gas	THP others	Total
2017	12,578	710	156	0.2	323	1,594	381	556	16,301
2016	12,568	689	125	0.2	2.1	1,518	381	512	15,815
2015	12,568	665	122	0.2	1.4	1,496	381	510	15,748
2014	12,568	665	100	0.2	1.4	1,452	381	498	15,668
2013	12,516	637	93	0.2	0	1,401	379	476	15,504
2012	12,210	614	79	0.2	0	1,346	374	453	15,078
2011	12,210	580	72	0.2	0	1,273	374	434	14,944
2010	12,210	521	68	0.2	0	1,159	374	416	14,750

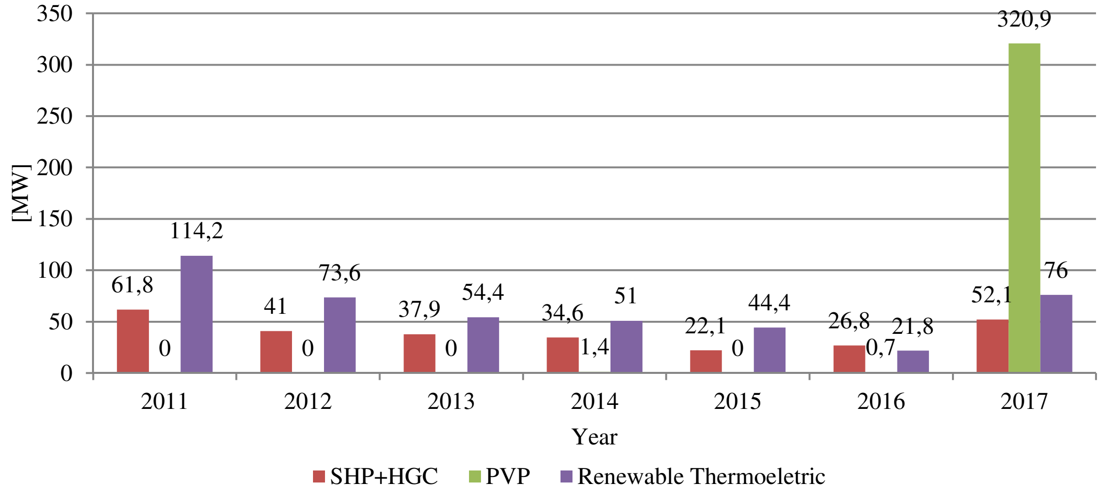

Figure 1. Annual renewable energy entry, except HPP, in the Minas Gerais electric matrix, by source, from 2011 to 2017 [MW] (adapted from [32])

Considering the different sources of renewable generation, the reduction of new installed capacity annually of renewable thermal source and small hydro is notable. In the case of small hydroelectric plants, however, there was a small increase between 2015 and 2016. The representative increase in the pace of the entry of new installed capacity of photovoltaic plants in the period was a positive highlight. Before 2013, there was no plant installed, while in 2017 the input of photovoltaic electric generation capacity was significant in relation to the other sources.

The share of renewable energy in the Minas Gerais electricity matrix, excluding HPP, increased in all the observed periods, as can be seen in Figure 2. Nevertheless, there has been a reduction in the rate of increase in the proportion of these sources from 2013 to 2016.

In 2017, the rate had a significant increase because of the new photovoltaic plants installed on the state. This result partially reflects what has been shown in Figure 1. The share of renewable energy continued to increase from 2013 to 2017, as the entry of installed capacity by non-renewable source decreased. However, with the reduction of new renewable energy ventures, the pace of growth in the share of renewables has not remained at the same level at the first three years of the PMER.

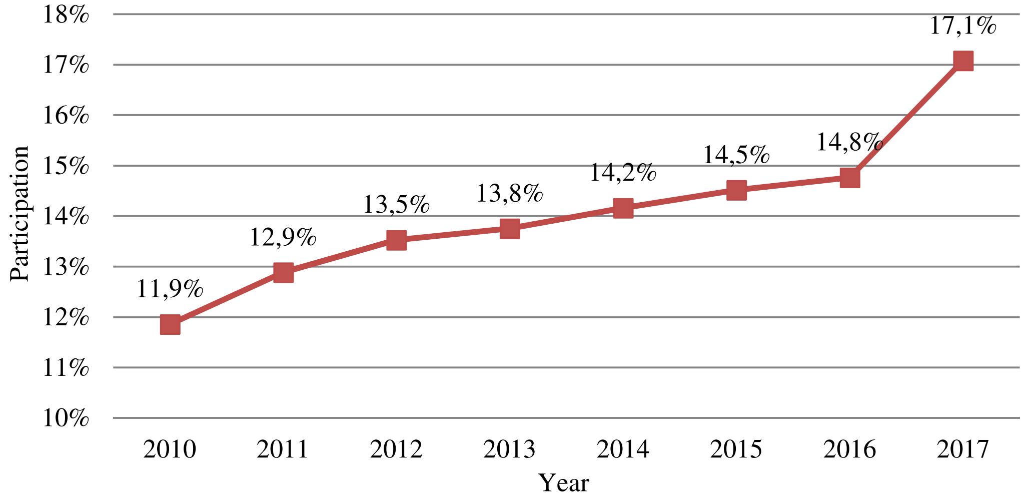

Figure 2. Participation of renewable energy, except HPP, in the Minas Gerais electric matrix, from 2010 to 2017 [%] (adapted from [32])

The total installed power of micro and mini-generation in Minas Gerais from 2013 to 2017 is shown in Figure 3. Since 2015, there was an increase of micro and mini-generation power installed in the state of more than 35 times. By February 2019, about 99% of the 13,889 micro and mini-generation plants installed in the state corresponded to photovoltaic generation [33]. The remainder consisted of generators from biogas, from urban, animal or agroindustry residues, or hydroelectric, or from blast furnace gas from biomass.

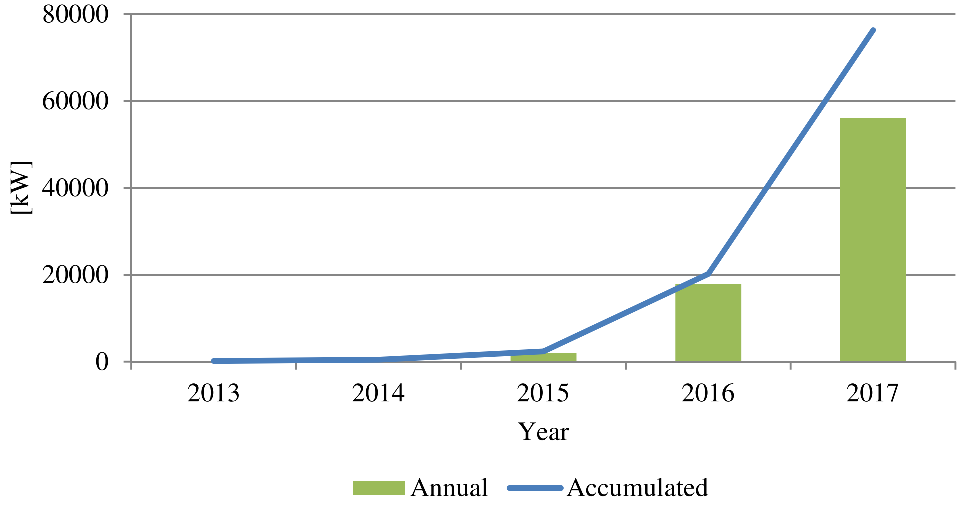

Figure 3. Installed power of micro and mini generation in Minas Gerais from 2013 to 2017 [kW] (adapted from [32])

It must be emphasized that Minas Gerais is the Brazilian state with the highest number of DG plants, as well as the state with greatest installed generation capacity of this type, as observed in Figure 4 (see Minas Gerais). This is due to the high potential of renewable sources in the state, specially the incidence of solar radiation, such as the high value of the electricity fare. The positive effect produced by the regulation of the ICMS for DG must also be considered, relieving the energy produced by these plants, not only because it improved the financial return on investments, but also because it demonstrated the state's commitment to the development of this technology.

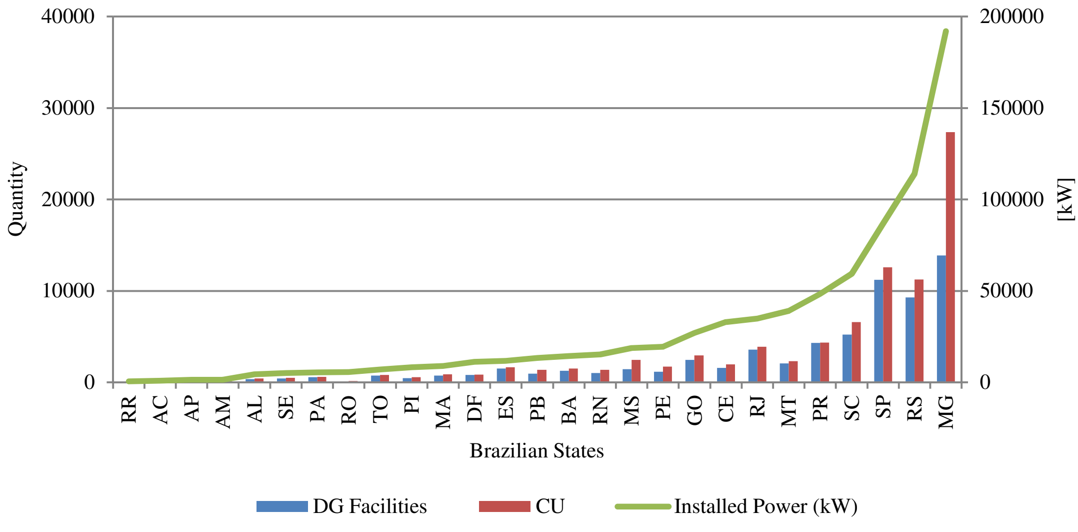

Figure 4. Number of DG facilities, number of Consumer Units (CU) served and Installed Power by Brazilian State in 2019 [kW] (adapted from [32])

Improvements in issues related mainly to environmental legislation coming from the PMER, also favoured the expansion of photovoltaic energy in the state, since it especially benefited the installation of projects of remote consumption.

Until the beginning of 2019 there was already DG installed in 650 out of 853 municipalities in Minas Gerais [33]. It is verified by these numbers that the use of DG technology tends to be higher in municipalities with higher income, but that there is still a great distribution of the installation of these projects throughout the state.

Innovation

The Decree Number 9073 of June 5, 2017 [16], which promulgates the Paris Agreement under the United Nations Framework Convention on Climate Change, celebrated in Paris on 12 December 2015, meets in part the requirements of the criterion of the first item, National Policy, since it has specific targets for the expansion of Renewable Energies. Nonetheless, although the PMER has common goals, it does not have the definition of a quantitative target in order to increase the number of projects over a specific period of time. Regarding the requirements related to the Law or Specific Strategy for Renewable Energies, it can be observed that there is no action in this sense at both, the national and the state levels, and the Ten-Year Energy Plan (PDE) [31] is in charge of establishing the guidelines for the expansion of the energy sector. It should be noted that most of the investments planned in the PDE are for the oil industry.

The results regarding the compliance with the requirements proposed by IRENA to set up an innovative policy to encourage renewable energy sources [28] can be seen in Table 6.

Table 6. Classification of instruments addressed by PMER

National policy	Regulatory instruments	Tax incentives	Network access	Financing	Knowledge and human resources
Decree No. 9073 of June 5, 2017 [16]	Priority in environmental regularization processes	ICMS exemption	Priority in the solicitation and access to the system	Partnership agreements for transmission lines	Technical and scientific cooperation
Ten-Year Energy Plan [31]	Priority in the formalization of energy purchase contracts	-	-	Specific funding line	Training and qualification of human resources

In case of the regulatory instruments, the program is also insufficient, since it has only two actions aimed at speeding up environmental regularization processes and energy purchase contracts. Important instruments, such as special tariffs and renewable energy certificates are not contemplated.

When it comes to the tax incentives, as well as regulatory instruments, the PMER has only the exemption of ICMS as an attraction for investments in the sector. In relation to the item of access to the network, PMER uses the same artifice of the item of regulatory instruments, which is to speed the requests of access to the network. There are no incentives for new transmission lines or other types of benefits.

In the financing item, PMER has a specific line of financing and contracts of public private partnerships for the construction of transmission lines. However, the creation of a specific fund would be a substantial differential for the program implementation.

In terms of socio-economic benefits, PMER foresees technical-scientific cooperation for the development of renewable technologies in the state territory, as well as the training of human resources in this area. However, there is a lack of specific actions to meet the needs of the rural population, as well as local programs.

Creation of jobs

It is possible to verify a growth in the number of jobs generated in the last three years from the expansion of renewable energy projects by the Table 7, combining data from Table 3 and [32]. It can be seen that from 2013 to 2017, the number of new jobs created were 6,374.32. In 2017, there was a substantial increase in employment generation, with more than 3,900 jobs created. In the latter period, the number of new jobs more than tripled in relation to the first year of the PEMR. In large part, it is due to the considerable number of photovoltaic plants installed on Minas Gerais, and also to the increase in the installed capacity of DG, which were the most developed in the state over this period.

Table 7. Generated jobs

Year	Average number of jobs generated by MW	New installed capacity from incentivized sources (it includes centralized and distributed generation) [MW]	New renewable energy jobs generated
2013	7.77	92.40	717.95
2014	7.77	87.28	678.14
2015	7.77	68.46	531.96
2016	7.77	67.09	521.32
2017	7.77	505.14	3,924.94
Total		820.38	6,374.32

Mitigation of Greenhouse Gases

FEAM has published in 2014 the GHG Inventory [34], and according to the document, emissions of around 124 Mt CO_2eq in the state of Minas Gerais were generated, with the energy sector accounting for about 37% of these emissions, i.e. 45.8 Mt CO_2eq.

The total emissions avoided over of the period of the PMER in relation to the expansion of the projects contemplated therein are shown in Table 8, using data from [30]. It is notable that, when compared to the number of emissions in the sector [34], the total avoided emissions represented around 0.365% in the year 2014. For the other years it is not possible to carry out the analysis since the emission data for the years 2015 and 2016 are not available.

Table 8. Avoided emissions of the electric sector in Minas Gerais

Year	Average annual factor [t CO_2/MWh]	Total [MWh/year]	Total emissions avoided [t CO_2eq]
2016	0.0817	2,050,795.0	167,549.95
2015	0.1244	2,002,287.0	249,084.50
2014	0.1355	1,943,482.0	263,341.81

The years 2014 and 2015 were characterized by a long period of drought that affected the water availability of the reservoirs of the hydroelectric power plants of Minas Gerais, therefore, it was necessary to activate fossil fuel thermal plants, causing an increase in the emission of GHG for those years [14]. With a more constant rainfall regime in 2016, the fossil fuel power plant was shut down and the emission factor decreased in that year.

Costs associated with the Program

Due to the fact that there are no reports published by State Secretary of Finance of Minas Gerais [Secretaria de Estado de Fazenda de Minas Gerais (SEF/MG)] regarding the budgetary impacts of PMER on state finances, this analysis will be performed in future studies.

CONCLUSIONS

The main effort of the State Government to promote the generation of electricity from renewable sources is through the Renewable Energy Program of Minas Gerais. The program has a limited scope and does not serve the renewable energy sector as a whole, as it does not address all the biofuels and the thermal power generation. Its largest contribution was in the tax breaks axis with the consolidation of tax exemptions for the generation of electricity by renewable sources, except for large hydroelectric plants.

Analysing the results obtained in this study, it can be observed that the electricity generation from renewable sources has grown in Minas Gerais, especially after the first three years of the existence of the PMER, however, it is not possible to make an association of this trajectory with the PMER. The data show the decrease of the entry of small hydroelectric and of biomass thermal plants in recent years, partially offset by the installation of solar ventures. The inversion of the path of decrease of the entrance of operation of small hydropower, however, can be a positive effect of the program.

According to the results, it can clearly indicate that the positive effects of the program are those related to photovoltaic energy. There is an evident expansion of the installed capacity of photovoltaic energy generation since 2013, when the PMER was established. The micro and minigeneration distributed specifically showed significant growth, although in terms of installed capacity, it still represents a small amount. However, it is not possible to define the degree of importance of the program for the realization of these ventures, considering that photovoltaic energy had other fundamental incentives for its development, originating from the Federal Government, market conditions and natural factors.

With reference to political innovation, the instruments addressed by the PMER are not enough to recognize the program as a robust, efficient and innovative policy for the promotion of renewable sources in Minas Gerais. Although meeting some requirements of the parameters proposed by IRENA, factors such as law and strategy specific to renewable energy are absent in the state. The lack of short-, medium- and long-term goals and guidelines also indicates the Government's low ambition on the issue. In addition, the PMER does not specifically go into the local context and the promotion of distributed generation, with their instruments taking a more general approach.

Just as there was an expansion of the installed capacity of renewable energy sources in the state, there was also an increase in the creation of new jobs from these ventures. It is worth noting the year 2017 when more than 3,900 jobs were created, probably due to the expansion of photovoltaic projects, which has a high rate of employability. However, it is not possible to attribute this increase with certainty to the PMER.

Regarding the mitigation of GHG, the period in which it has been analysed did not show large reductions in the emissions of the sector, since, taking 2014 as the base the year, the mitigation of gases was less than 0.5% of the value issued in the year. Taking into account a growing increase in the demand for electric energy, it is possible to affirm that the emissions will also be increasing if the sources of renewable energies do not assume a more active role. Increased generation and consumption of renewable energy for sustainable development and to combat climate change depends heavily on public policies that improve the business environment and encourage investment in the sector. In order to accelerate the development of renewable sources in the State, it is important that the actions foreseen by the State Renewable Energy Program of Minas Gerais be strengthened and resumed. Complementary actions are also necessary to better define the objectives of the program, to include other renewable sources not envisaged and to provide for further development instruments. Thus, it is considered necessary to reformulate the PMER so that it can assume the role of strengthening the actions of the State Government to promote renewable energy and the decentralization of the targets for compliance with the Paris Agreement, signed at the federal level.

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