Type of the Paper: New Article.

Renewable Distributed Generation Evolution in the Brazil and Italy between 2000-2021

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Abstract: The traditional power systems structure is based in the large power plants are located in areas typically is far from the consumer centres. In the last two decades a new paradigm, based on renewable distributed generation (RDG). Adopting RDG, consumers become prosumers and are able to increase autonomy and energy savings. However, its implementation is potentially disrupting to electric sector, generating divergence of interests among regulators, users and distribution companies. This work discusses the growth of the RDG model in the energy system transition processes to decarbonisation via electrification, digitalization, decentralization and democratization by analysing the development of RDG in Brazil and Italy in a comparative perspective of evolution. The methodology is qualitative, descriptive and exploratory. The findings indicate that RDG gained traction in Brazil with some specific regulations of the Brazilian National Agency, from 2012 on, where RDG share has been expanding significantly using the net metering model. In Italy, RDG assisted an impressive growth from 2009 to 2012, based on the feed in tariff, but as stagnated in the last decade. Both countries enacted recently a new legal framework to pave a RDG expansion cycle to tackle climate targets. The RDG can be significantly enhanced in both countries as long as there are adequate regulations, and it is an opportunity to develop decarbonisation, electrification, digitalization, decentralization and democratization of the respective electricity sectors.

Keywords: Renewable Distributed Generation, Prosumers, Energy Transition, Legal Framework, Brazil, Italy.

1. Introduction

The current paradigm for electric power generation systems is still based on large plants located in areas where it is more convenient to build them. The back bone of the system is supported by an interconnected and centralized transmission grid that allow the displacement of large quantity of electricity produced usually very far away from the main consumer centers (manly cities and industrial hubs). However, the transmission lines have limits to the power that can be carried, which may imply in curtailments, with generations plants and entire areas being unable to exchange or delivery the electricity produced. The lines also present energy losses in the transmission and distribution processes. Moreover, the construction and expansion of these large transmission infrastructures are complex to plan, expensive and time-consuming, being hard to implement due to land multiple uses and legal restrictions, especially property rights and environmental aspects.

Furthermore, in the last two decades advances in renewable technologies and batteries, are open up expansion vector in the generation side, allowing the emerge of a new paradigm, based on renewable distributed generation (RDG) implemented direct at the level of the electrical distribution network.

Around the world, users, supported by different incentive schemes are adopting RDG become simultaneously consumers and producers of electricity (prosumers), which has the positive impact production locally, increasing user autonomy and savings in terms of electricity costs. In addition, photovoltaic (PV) solar energy has been the most used energy in this energy transition process with RDG.

Nowadays, the 5 main vectors of the *energy transition are* [1-7]: *decarbonisation, electrification, digitalization, decentralization and democratization are identifying in the literature*. These 5 vectors can orient the RDG model development toward energy sustainability in cities, being the focus of this article Brazil and Italy.

The term "decarbonization" indicates the declining average carbon intensity of primary energy over time thanks to the exploitation of new and clean energy sources. Decarbonization targets in most parts of the world have been set recently at a worldwide level for the first time at Conference of the Parties (COP21) in Paris in 2015. COP22 in Marrakech in 2016, called "the COP of the action", opening the way to the practical implementation of the Paris COP21 agreement [2, 3]. COP26, held in Glasgow in 2021, and the most recent reports from the Intergovernmental Panel on Climate Change (IPCC) [8] reaffirm the urgent need to decarbonise the world energy sector to combat global warming and climate change. The war in Ukraine added another stream line in the processes to the independence from fossil fuels.

Decentralization and electrification, particularly relevant in the urban environment [4, 5], have become two major, intertwined decarbonization pathways due to the stark technological improvements (incl. digitalization) and growing political support of efficient, electricity-based mobile and stationary energy converters and storages, such as heat pumps and electric vehicles [2, 4, 9, 10].

While classical non-renewable electricity generation units can predictably dispatch power on demand in that regard, they face challenges of relatively high emission intensities due to the commonly used fossil energy carriers. On the contrary, the installation of renewable energy technologies, such as photovoltaics (PV), can reduce supply's carbon footprint but brings along challenges of seasonality, intermittency, and non-dispatchability. Energy storage systems may alleviate these concerns but add cost, storage losses, complexity, and embodied emissions to the energy system. Whether to implement such supply systems as decentralized energy systems, i.e. via small scale converters and storages in close proximity to the consumer but with relatively high specific investment cost and embodied emissions, or whether to invest into centralized technologies, which profit from economies of scales but require costly and lossy transmission and distribution infrastructures to supply energy to the end users, increases the complexity of energy system planning [4].

The success of electrification is however largely dependent on the geographical and temporal availability of affordable, reliable and environmentally-friendly electricity, which is not equally distributed across the globe, as indicated by the Energy Trilemma ranking [4, 11]. Hence, to enable electrification, depending on the geographical location existent electricity supply must be upgraded by installation of new electricity generation, distribution and storage technologies as well as corresponding integration methods [4].

In these regards, the two selected countries are similar in the fact that they have the best renewable resources (solar and wind) located in geographical areas that are opposite from the areas of greatest demand (northeast - southeast in the Brazilian case and south - north in the Italian case) (Figure 1). In terms of solar power potential, the Brazilian photovoltaic generation potential is higher than the Italian one, due to having more areas and to have higher levels of solar irradiation. However, in both cases, restrictions on the transmission capacity of transferring generations' surpluses are already inhibiting the installations of new renewable energy (RE) centralized generations' plants. Accordingly, when planning new energy systems complex trade-off decisions between centralized and decentralized, renewable and non-renewable, and electrified and nonelectrified assets are inevitable and should ideally simultaneously ensure affordability, sustainability, and energy security [4].

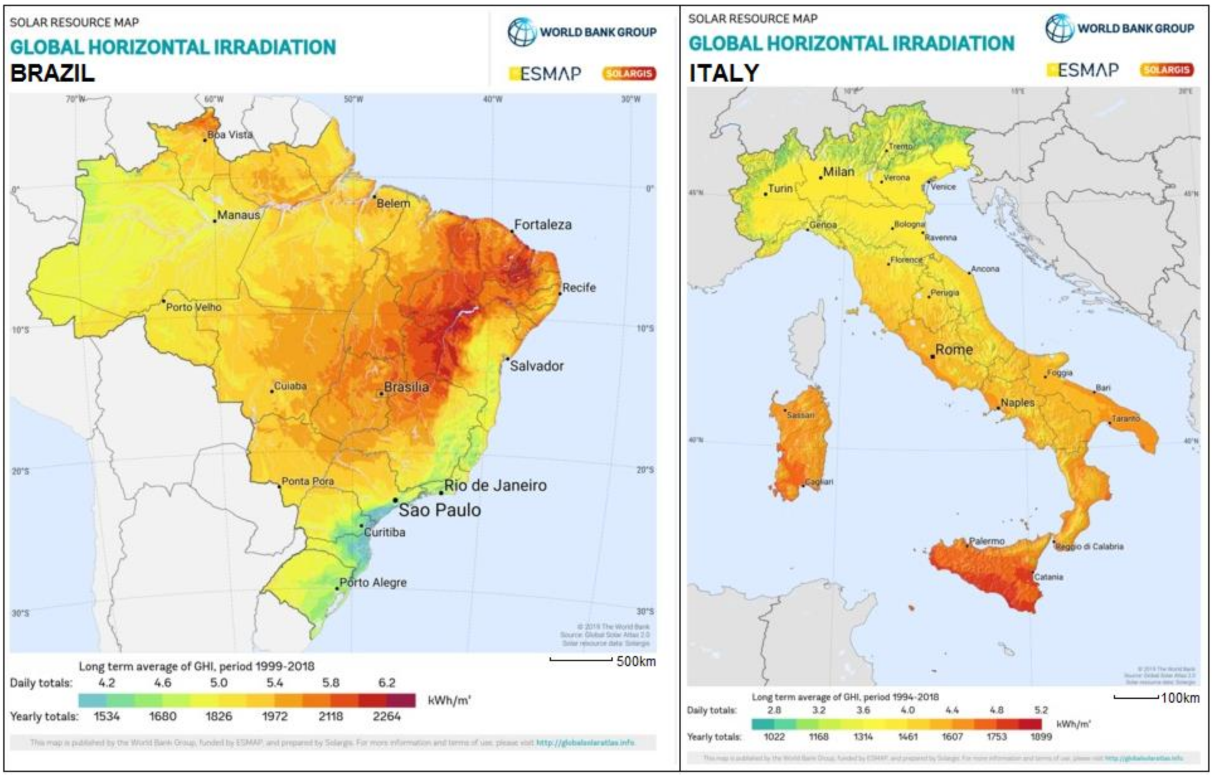

Figure 1. Solar Radiations Comparative of Brazil-Italy [12].

Thanks to Digitalization, the world is experiencing a 4th industrial revolution [2, 13]. According to Gartner definition, Digitalization is "the use of digital technologies to change a business model and provide new revenue and value-producing opportunities; it is the process of moving to a digital business" [2, 14]. The World Economic Forum indicates three technologies as the most revolutionary in the field of Digitalization: Cloud, Internet of Things (IoT) and Mobile [2]. Concerning power systems, Decentralization indicates the tendency of generating and managing electricity close to the load centers by using distributed generators connected to the LV and the MV grids. The concept is closely linked to Decarbonization and Digitalization since the most of the generation units are RES-based plants that must be coordinated in order to achieve security and efficiency [2].

The democratization of the energy industry covers a very broad field. This includes the possibility of many individuals becoming electricity producers themselves [6, 15]; however, this also requires addressing the desire for social participation in energy issues [6, 16] and tackle energy poverty. The founding of numerous public utilities, the re-municipalisation of many electricity distribution networks [6, 17], the establishment of hundreds of energy cooperatives [6, 18] and the great interest in bio-energy villages, energy-autonomous municipalities, etc. are an expression of a change in social awareness [6, 19]. It is also an expression of growing distrust of large energy supply companies and a system for the provision of services of general interest that is predominantly based on shareholder value [6].

In the last decade, as shown in Figure 2 and 3, PV technology has had a significant reduction in its costs and an improvement in its capacity factor, which has increased its competitiveness and attractiveness in several countries (Figure 3) for the use of RDG. This cost reduction boosted the expansion of photovoltaic DG (PVDG) and paved the way for the 5 D's directly for consumers. As a result, several countries had PVDG growth, and the situation in Brazil and Italy will be discussed.

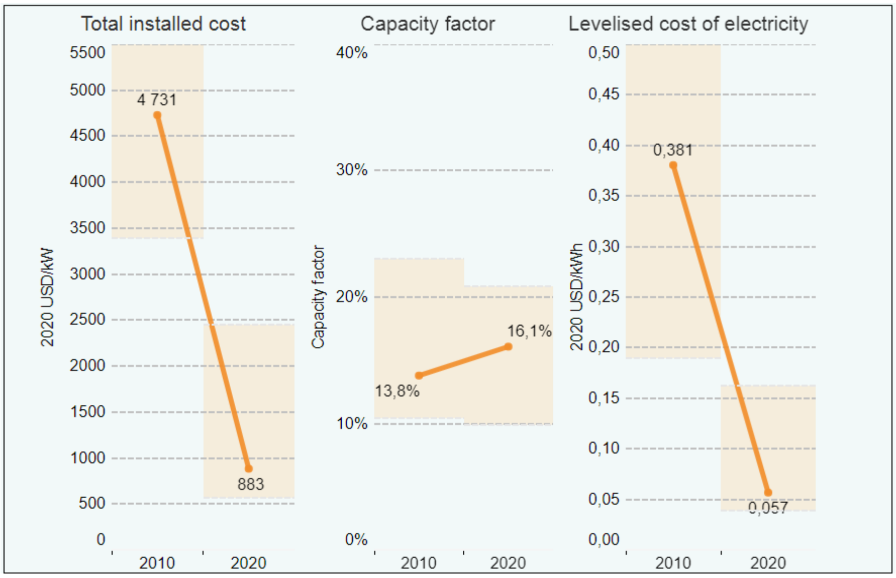

Figure 2. Evolution of costs, capacity factor and LCOE of PV Solar energy [20].

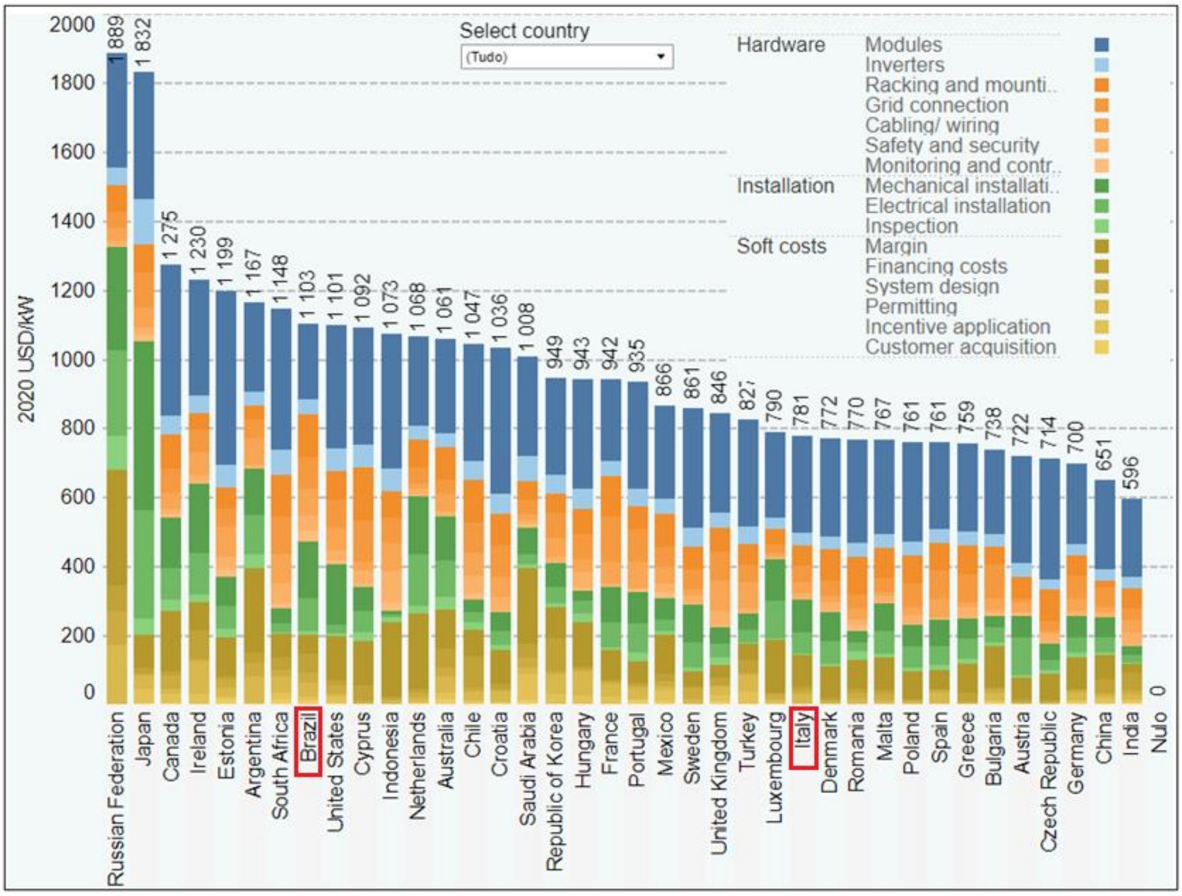

Figure 3. Solar Radiations Comparative of Brazil-Italy in 2020 [20].

2. Scope and specific objectives

This work focuses on socio-political issues and discusses the growth of the RDG model oriented by 5 main vectors of the energy transition: *electrification, digitalization, decarbonisation, decentralization* and *democratization*, by considering the development of RDG in Brazil and Italy. It also analyses the RDG evolution in a comparative perspective of Brazil-Italy and present scenarios about energy sustainability in cities.

The specifics objectives are: (i) analyses the RDG evolution in a comparative perspective of Brazil-Italy and present scenarios about energy sustainability in cities; (ii) point out to legal recommendations for improve the development of the RDG.

3. Methodology

The present work used multiple research methods [21], blending systematic literature review [22] for data collection and the functional method of comparative law [23], discourse analysis [23] and triangulation [23] for data analysis, performing thus qualitative, applied, descriptive and exploratory research.

In the pre-research phase, an exploratory literature research was carried out and then later consolidated through a systematic literature review, including Scopus and Science Direct/Elsevier databases, from the period of 2000 to 2021. This was carried out in English, using terms such as: "energy community", "distributed generation", "Italian electrical legal framework", "energy transition"; "collective energy scheme"; "renewable energy", "Italian *Milleproroghe* Decree", "Income and Energy Generation Program", "ANEEL Resolution Nº. 4.385/2013" [24], "Energy Community", "Italy" and "Brazil". Grey literature such as legislation, regulatory agency documents (Italian Authority for Electricity, Gas and Water System - ARERA, Italian Energy Services Manager - GSE, Brazilian National Electric Energy Agency – ANEEL and Brazilian Energy Research Company - EPE), technical reports (International Renewably Energy Agency - IRENA, IEA and European Commission), project reports and international media news, among others, were also selected and analyzed. Despite the inclusion of publications from 2022 in the references, considering the year is still in progress, such works were not filtered by the systematic review of the literature.

The research, therefore, was divided into the following stages: (i) survey of literature for the characterization and analysis of the current energy context and framework, nationally and at European level, with a focus on RDG; (ii) analysis of the political and socioeconomic context of Italy and Brazil, the impacts of regulations in the development of both electricity sectors in recent years; (iii) selection and evaluation of the so-called determining factors; (iv) construction of hypotheses that contemplate regulatory proposals to improve Italian and Brazilian regulation in the RDG framework; (v) analysis of the material collected and writing up.

Based on a study of the laws enacted so far and through the literature survey and study analysis, the present work aims to collaborate to promote the current implementation process of RDG established by the Directives of the CEP in Italy and by Law N. 14.300/2022 [25] in Brazil. Suggestions are made to improve the creation of the legal framework of the electricity sector for RDGs in the countries. The suggestions presented attempt to offer a more coherent national framework for the electricity sector in the selected countries, improving flexibility, resilience and sustainability in cities' electricity grid, based in 5 expansion vectors (decarbonisation, electrification, digitalization, decentralization and democratization), through the lenses of eco-efficiency, social equality, safety and energy democracy.

4. Results

4.1. Comparison Context of Realities Brazil – Italy

The geographic and socioeconomic (Table 1) realities between Brazil and Italy are different. Brazil is located in South America and Italy in Europe. Brazil has a geographic area of 8,515,767 km^2, population density of 25/km^2 and human development index (HDI) of 0.765 in 2019. Italy has a geographic area of 301,230 km^2, population density of 201.3/km^2 and HDI of 0.892 in 2019. Brazil in part of the global south, while Italy is part of the south of Europe, having similar relative positions in the global and European context, respectively, despite the first being a developing country and the second an already developed one (Figure 4).

Table 1. Comparison of some Brazil-Italy socioeconomic indicators [26]:

Nº	Indicators	Brazil	Italy
1	**Population in 2020**	212,559,409	59,729,081
2	**Life expectancy at birth in 2019**	75.9 years	83.2 years
3	**GDP total in 2020**	US$ 1,445 Trillions	US$ 1,889 Trillions
4	**GNI per capita in 2020**	US$ 7,850	US$ 32,290
5	**CO_2 emissions (metric tons per capita) in 2018**	2.042	5.376

The observation of images of night lighting in urban areas in Brazil and Italy (Figure 4) [27], it is also possible to notice the differences in terms of territorial urban concentration. In Brazil, night lighting indicates urbanization concentrated on the coast and in some large cities in the interior. In Italy, urbanization is more evenly distributed. Discrepancies in territorial dimensions, HDI and historical differences are the reasons for such differences.

Figure 4. Night images of Brazil and Italy obtained of NASA/Google Earth in 2016 [27].

4.2. Brazilian and Italian Outlook and Evolution Renewable Distributed Generation: Period 2000 – 2021

RDG, especially photovoltaic, in Brazil has drawn the attention of society and has become relevant since 2012 [28–44]. According to ANEEL (Table 2) [45] and EPE [46], from ANEEL normative resolution N. 482/2012 [24], the growth of the Brazilian DG became practically exponential, where the number of RDG systems connected to the electricity grid reached almost 830 thousand and installed capacity reached around 9.2 GW in 2021.

Table 2. Distributed Generation Development in Brazil: 2000 – 2021 [45]:

Year	2000-2007	2008	2009	2010	2011	2012	2013	2014
DG connections	0	1	2	6	7	6	58	305
Power (kW)	0	25.00	23.00	40.02	101.00	467.22	1,493.46	2,795.68
Year	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**TOTAL**
DG connections	1,458	6,717	13,945	35,958	124,076	224,140	420,780	**827,074**
Power (kW)	17,032.60	65,467.97	162,382.54	401,547.43	1,581,620.14	2,828,945.32	4,152,058.04	**9,213,999.42**

In Italy RDG, also in the almost totality photovoltaic, has drawn the attention of society and has become relevant from 2005 on with the Feed in Tariff incentive called *Conto Energia* that finished in 2013, after 5 years. According to GSE [47] and TERNA [48] (Table 3), between the third and fifth year the growth of the Italian RDG was exponential, became almost flat in the coming years. In 2021, the number of RDG systems connected to the electricity grid exceed 1 million and installed capacity reached 25.5 GW.

Table 3. Distributed Generation Development in Italy: 2000 – 2021 [47, 48]:

Year	2000/2007	2008	2009	2010	2011	2012	2013	2014
DG connections	7.647,00	27.158,00	41.788,00	84.343,00	174.422,00	150.048,00	110.949,00	51.841,00
Power (kW)	87	344,00	1.263.569,00	2.328.000,00	9.539.000,00	3.654.000,00	1.400.000,00	409.000,00
Year	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**TOTAL**
DG conenctions	39.563,00	44.294,00	41.961,00	48.287,00	57.789,00	55.748,00	79.401,00	**1.015.239,00**
Power (kW)	307.000,00	382.000,00	399.000,00	426.000,00	757.000,00	785.000,00	937.000,00	**22.587.000,00**

When comparing the evolution of DG in Brazil and Italy in the period 2000 – 2021 (Figure 5), the differences in the growth curves are noticeable. Brazil presents an exponential curve while Italy presents an elevation curve until 2011 and then presents a reduction in the pace of implementation of new DG systems.

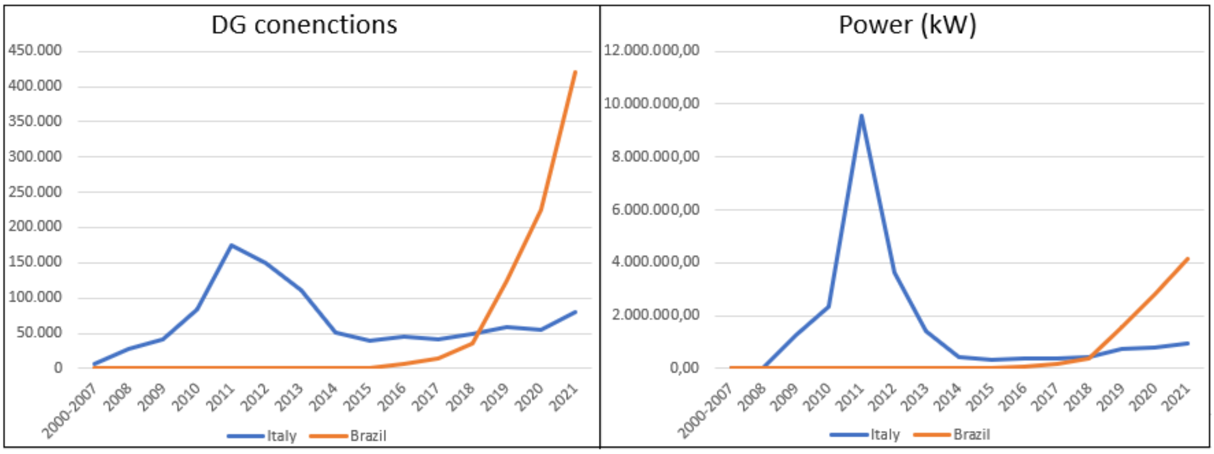

Figure 5. Comparative Distributed Generation Development Brazil- Italy: growth by year during 2000 – 2021.

4.3. Legal Structure of Electricity Markets in EU/Italy and Brazil

The structure of the EU electricity market has been widely discussed in recent years at the European level [49]. This sector has increased the share of renewable energy generation up to 32.1% in 2018 [50]. However, the EU also suffers from a rise in emissions, high levels of unscheduled and reverse flows and an increase in redispatch costs, which are partly due to the suboptimal geographical zone configuration of the market and distribution of the RE resources available [49]. Despite the commitments announced and the intention to become the first carbon neutral continent, the EU is still one of the biggest GHG emitters and their commitments are not yet aligned to the goals of the Paris Agreement.

Furthermore, the increasing penetration of variable renewable energy generation will increase the challenges of balancing and controlling the energy flows. For energy transition in Europe, 21% of solar and wind generated electricity in the grid is foreseen by 2030 (from a total share of renewable electricity of 41%) in the reference scenario and 29% from 50% of the total share in the REmap scenario [51]. The variable generation from the renewable energy sources and the less-than-optimal configuration of the electric system (policy, market and geographic aspects) is becoming a limiting factor for the efficiency of the integration process of the electricity market [49, 52, 53].

In December 2021 Italy promulgated the national law for the transposition of the Renewable Energy Directive with the Legislative Decree 199/2021 [55] and the Directive on the Internal Electricity Market was transposed with the Legislative Decree 210/2021 [57]. The both laws, when fully applicable, should unblock investment in renewables, to accomplish the objectives established in the Integrated National Energy and Climate Plan (PNIEC) which foresees a total of 51 GW of PV generation by 2030 due to a 30 GW capacity increase in this next decade [58]. Nevertheless, the normative acts from the ARERA were delayed and should be enact only in September 2022. To date, several aspects regarding RDG foreseen in the new laws, specially involving collective self-consumption and energy communities are treated by the Law n. 8/2020, that implemented an experimental phase design to collect data and useful elements for the final implementation of the Directives.

The main form to incentivize the RDG established by the CEP are implemented by four different concepts of collective energy self-consumption, namely: renewable energy communities (RECs), citizens energy communities (CECs), renewables self-consumers and active consumer (EU, 2018 and 2019) and introduced the concept of energy shared within the scheme members, which is equal to the minimum between the electricity produced by the community generation facility and the electricity withdrawn by all the associated members at the same time. Energy is considered shared for instantaneous self-consumption also through storage systems [59, 60].

These new schemes bring a paradigm shift to the energy markets by promoting new ways of engaging citizens and the private sector in the production and consumption of RDGs, by given the possibility to play active role in the energy market. It is worth noticing that before the CEP, the incentives to the private sector to participate in the generation of RE around the world could be classify into two main schemes: the feed in tariff (FIT) or the compensation by net metering. In both cases are required little attention towards active consumption, since it was being implemented in the passive logic of “feed and forget”. The collective models proposed by CEP, however, established the need to match energy production and consumption, thus requiring more user's awareness in relation to the production process, and even more regarding their own consumption profile. These aspects were implemented aiming to stimulate virtuous behaviours, promote flexibility in consumption, to favour a greater insertion of variable renewable sources, mainly solar and wind [61, 62, 63].

In Brazil, electricity sector regulation is fragmented in several normative documents, and the current legal framework to RDG is the result of the last reform implemented by Law N. 14.300/2022 (DG New Legal Framework) [25]. This law was responsible for perpetuating the compensation system (Net Metering) original implemented by the ANEEL Resolution 482/2012 [24]. It defines the electric energy compensation system, the concept of shared generation and enterprise with multiple consumer units, among other measures. Under the current regulation, individual properties, condominiums, cooperatives and consortia can be included in micro and mini modalities, participating in the energy market through the net metering scheme.

Brazilian Energy Research Company (EPE) in the last Ten-Year Energy Plan (PDE 2029) estimates that Brazil will have 1.3 million micro and mini-energy facilities distributed by 2029, equivalent to 11.4 GW of installed capacity [64]. There is, however, no official concern or incentive that focuses specifically on ECs in Brazil. In fact, EPE [29] estimates that by 2050 only 13% of residential total demand will be supplied via distributed generation. This hampers RDG because large-centralized ventures enjoy many benefits, such as special financing conditions (funding provide by public development bank with long term repayment and low interest rates) and long-term energy sales contracts with DSOs, in addition to gains of scale, creating utility scale lock-in technology for PV in the country [65-67].

The official estimate of distributed generation growth in Brazil by 2050, prepared by EPE [29], is relatively modest in view of the growth potential of PV distributed generation in the national market. This might be due to a previous concern about the impact that robust growth of distributed generation would entail in the income of DSOs and energy trading companies, as well as tax revenues on electricity. The Federal and State Governments will probably collect less tax, but the impact of lower electricity costs could be compensated with part of the savings going to more consumption in the economy, more competitive prices for industrial production and greater business investment in production, starting a growth cycle in the economy [67].

5. Discussion

Good policies provide a strong foundation for action on energy efficiency and RDGs growth, which can improve electrification for final users, replacing fossil fuels with electricity and boosting energy savings. Enabling a smooth switch from fossil fuels to renewables is necessary to build the pathway for the energy transition, by lowing the carbon content of electricity (g/kWh) and emissions on a timescale with objectives and goals across the next decade. However, much work remains to be done to modernize traditional utility business models to encourage energy efficiency. These include revenue decoupling and implementing performance incentive mechanisms to limit the carbon content of electricity (g/kWh) and GHGs emissions.

SEB is a world reference in terms of low carbon intensity. But it runs the risk of increasing the amount of CO_2 due to the entry into operation of very old thermal plants and the implementation of new thermal plants. The insertion of REs (Wind, Solar PV, biomass, etc.) will help to maintain and increase the decarbonization of the SEB. In this context, PVDG is quite relevant. Its carbon intensity according to Balance Energy National 2021 [69], the Brazilian Electricity Sector emitted 78.8 kg CO_2-eq/MWh in 2020. Italy in terms of decarbonization reduced by 19% the GHGs emissions between 1990 and 2020. Nevertheless, in 2020, 57% of Italian electricity still been generated by fossil fuels, being 50% by gas, having the Italian grid a carbon intensity of 258.8 kg CO_2-eq/MWh in 2017 [70]. Both countries have presented evolutions in terms of decarbonization, by the expansion of modern sources of RE (solar and wind). However, Brazilian situation is better than Italian, since the first has its load base provide by hydropower, which can provide more flexible, cheap and emission-free generation, then gas, which function as the baseload of the Italian power system.

Brazil still has electrification deficits in its more isolated regions (i.e., many locations in the Amazon region). In the urban environment, electrification is provided to the almost totality of the population. Nevertheless, the poor population in Brazil usually live on outskirts of cities or in slums (favelas), with lower quality or even precarious and illegal electrification access. In many cases, the inhabitants of the Brazilian favelas resort to power theft (popularly known as “cats”). Italy in terms of electrification, the access is provided to entire population. Both countries have yet evolutions to make in terms of electrification. However, Italian situation is a better than Brazilian situation because Brazil has many no electrification areas that Italy. It is worth noting that electricity tariffs have increased significantly in recent years in both countries and the less favoured layers of the population are suffering to keep the bills in check. Additionally, the future demand that electric vehicles and smart cities will add in both countries will require adaptation of the electric distribution networks.

Brazilian Electric Sector (Generation, Transmission, Distribution and Commercialization), as a whole, is still relatively little digitized. In generation, sector companies currently implement infrastructures with a high degree of digitalization (automation, control and telecommunication). The transmission and distribution sectors are much less digitized. Brazilian Electricity System Operator (ONS) and the Italian National Electricity System Operator - TERNA concentrates the activities of digitalized supervision and coordination of electricity transmission. As rule, there is still no internet of things (IoT) and Blockchain available to the consumer. Distributed generation has helped in the digitalization process of the distribution network due to the need to implement bidirectional meters. Italian situation is a better than Brazilian since almost 98% of the meters a bidirectional and digital, even if from first generation. In both countries the electrical network needs significant investments to expand to cope with the new RE centralized generation and to absolve new technologies like sensors and automatic controls, improving its digitalized tools.

Brazilian and Italian Electricity Sectors are still quite centralized, as large generating plants predominate and it probably continues like this for many decades to come. However, the wave of RDG expansion gained traction in Brazil and it is turning back in Italy. Both countries have yet evolutions to make in terms of decentralization. However, Italian is implementing an incentive system based upon the matching between local production and consumption with the collective energy schemes. Brazil in other hand renewed the net metering system, implemented in 2012. The Brazilian system made RDG gain prominence in the last decade, however, it present limits, since that it is the grid that must function to provide flexibility and storage the energy in the water reservoirs.

In terms of democratization of energy supply, even with both small and large consumers are adopting distributed generation in the analysed countries, both still have a lot to develop in terms of RDG, since this still represents an adhesion of less than 5% of the total population. In addition, the RDG systems are concentrated in the most favored regions and social classes, thus not presenting a factor for reducing energy poverty or promoting social sustainability in the urban areas.

Some recommendations to promote the evolution of RDG in Italy and Brazil are:

a) ensuring access to relevant information and data, which are indispensable for the planning and constitution of RDG, especially regarding collective energy schemes;

b) the necessity of integrating existing generation systems in the schemes;

c) greater consideration to provision of flexibility and ancillary services, incentivising storage deployment;

d) promote awareness by inclusion of mandatory customized feedback to users on energy savings and carbon intensity reduction;

e) enabling users to respond to price signals, promoting behavioral changes, building retrofits and helping to increase the resilience of the electricity grid in the near future.

6. Conclusions

The information and results point to the growth trend of the RDG configuration in Brazil and Italy as relevant and likely to be leveraged through adequate regulations.

Both Brazil and Italy are still very new to digitization, decentralization and democratization in their respective national electricity sectors. In this case, the expansion of the RDG helps to advance the 3 aspects because: (i) it demands the use of bidirectional digital meters and improvements in the electrical network; (ii) enables greater independence of consumers in relation to centralized generation, especially if there is associated storage; (iii) with the reduction of costs and popularization of the RDG, more and more consumers are adhering to its use and, if there are public policies for the poor population, its expansion will be even greater.

In terms of electrification, Italy has a higher level of electrification than Brazil, especially in its rural areas. The differences in HDI and territorial dimensions influence this aspect.

Brazil, for having an electrical matrix with a large share of renewable energies (hydro, wind, biomass and solar) is currently quite decarbonized, but can further expand the use of renewable energies through the RDG. Italy is still very dependent on fossil fuels in its electricity matrix and the RDG is an interesting opportunity to reduce this dependence and help in the decarbonization process.

Thus, in general, the RDG can contribute significantly to decarbonisation, electrification, digitalization, decentralization and democratization of the electricity sectors in both countries.

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