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Trends in the use of biomass for energy generation for a province in the Central Region of Argentina

Agostina Lucía Quicchi [a], Mariana Del Valle Bernard [a], Diego Martín Ferreyra [a] & Gustavo Alejandro Schweickardt [b]

[a] *Facultad Regional San Francisco, Universidad Tecnológica Nacional, San Francisco, Argentina. aquicchi@facultad.sanfrancisco.utn.edu.ar, mbernard@facultad.sanfrancisco.utn.edu.ar, dferreyra@facultad.sanfrancisco.utn.edu.ar*
[b] *Facultad Regional Concepción del Uruguay, Universidad Tecnológica Nacional, Concepción del Uruguay, Argentina. gustavoschweickardt@conicet.gov.ar*

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Abstract
In this work, analyses are performed on international reports applicable to Argentina regarding the use of biomass for energy generation. More specific trends in the national context are also analyzed, and then a more detailed study is performed for Córdoba, one of the three provinces in the so-called Central Region. Córdoba was chosen not only due to its large availability of biomass and wide range of agricultural production, but also because of its favorable regulation promoting energy generation with regional biomass. It becomes clear that projects using dry biomass are very limited in number and scale in this province. Considering previous studies, including articles by the authors on energy applications of regional biomass such as sorghum, esparto grass or corn, it can be hinted that the use of dry biomass resources for energy generation is well below the capacity in the chosen province.

Keywords: energy crops; biofuels; biomass residue; bioenergy; biomass energy.

Tendencias en el uso de biomasa para generación de energía en una provincia de la Región Centro de Argentina

Resumen
En este trabajo, se evalúan informes internacionales sobre el uso de biomasa para generación de energía en Argentina. También se analizan tendencias específicas del contexto nacional y luego se estudia más detalladamente Córdoba, una de las tres provincias de la denominada Región Centro. Se elige Córdoba no solo por su gran disponibilidad de biomasa y amplia variedad de producción agrícola, sino también por su normativa favorable para promover la generación de energía con biomasa regional. Resulta evidente que los proyectos con biomasa seca son muy limitados en cantidad y escala en esta provincia. Teniendo en cuenta estudios previos, incluso artículos de los autores sobre aplicaciones energéticas de biomasa regional como sorgo, espartillo o maíz, se revela que el aprovechamiento de los recursos de biomasa seca para generación de energía está muy por debajo de la capacidad de la provincia seleccionada.

Palabras clave: cultivos energéticos; biocombustibles; residuo biomásico; bioenergía; energía de la biomasa.

1 Introduction

Biomass is understood as all organic matter of biological origin, including materials resulting from its natural or artificial transformation. It is one of the most reliable and adaptable renewable energy sources and can be stored, which facilitates its conversion into thermal and electrical energy [1].

In recent years, the use of biomass for energy purposes has been included as one of the priorities in several countries. However, there are still certain difficulties associated with

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the political, institutional, economic, sociocultural and environmental context that have a direct impact on the advancement of biomass for energy purposes [1].

Globally, bioenergy is the largest renewable resource available, accounting for 12 % of total energy consumption for various uses. Nevertheless, the traditional use of solid biomass such as firewood, charcoal and crop residues accounts for more than 50 % of total bioenergy consumption [2]. As a result, the growth in the production and use of modern bioenergy is crucial for the energy transition, since it not only involves different technologies of higher efficiency such as gasification, cogeneration plants, and biogas systems, but also employs different types of fuels, including pellets, biogas, biomethane, and agricultural and forestry residues. The modern use of biomass allows for a better use of energy and reduces greenhouse gas emissions, but it is important for its development to be managed sustainably and with appropriate policies. This article will analyze the use of biomass for energy generation, particularly electricity, first from a global point of view, then focusing on Argentina, and finally on a particular region of this country.

2 International trends

From 2009 to 2019, electricity from bioenergy doubled and, according to the current forecast by the IEA (International Energy Agency), this trend will continue between 2020 and 2030, although its growth is very gradual compared to the contribution of other renewable energies. Based on IRENA’s data (International Renewable Energy Agency), in 2020, 29 % of the world's total electricity generation will come from renewable energies, mainly hydroelectric, wind and solar power. In 2020, bioenergy accounted for only about 2 % of the total installed electric power and contributed about 3 % of the total electrical energy generated, although it is noted that electricity from bioenergy increased by 6.7 % that year compared to 2019. In IRENA's reports, the term "bioenergy" includes three different categories: biogas, liquid biofuels, and solid biofuels and renewable waste [2, 3].

Currently, biomass continues to grow steadily in electricity generation, but with a relatively low share and practically constant values, with China, India, the United Kingdom, Brazil, the United States, and the European Union having the largest installed capacity [2].

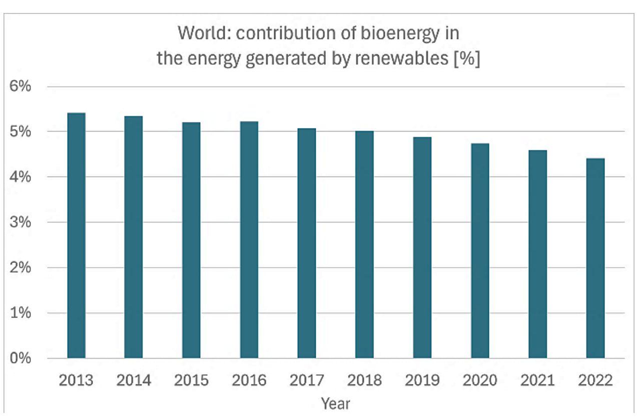

Figure 1. Contribution of bioenergy in the total energy generation by renewables in the world [%].
Source: The authors, based on public data from the IRENA, 2023 [4].

Fig. 1 shows the contribution of bioenergy to global electricity generation from renewable sources over the years.

It can be seen that biogas, solid biofuels and renewable waste represent almost all the bioenergy used for electricity generation, while a marginal percentage corresponds to liquid biofuels. This figure shows a decreasing trend in the percentage contribution of bioenergy in recent years [4]. This means that, although the total electricity generation from biomass increases annually in the world, the other renewable sources grow at a higher rate.

Of the 3 % of electricity generated from bioenergy, 90 % corresponds to the use of solid biofuels such as pellets, bagasse, and renewable municipal waste. It is interesting to note that the use of pellets has increased recently, although they are mostly used for heating: Russia, Vietnam and the United States are the main exporters of biofuels [2].

It is important to mention that, in Europe, the final cost of wood pellets for domestic use in 2018 was about 16 USD/GJ. This shows that it is a fully competitive option compared to natural gas, whose price ranged in the same year between 14 USD/GJ and 35 USD/GJ, depending on the levels of VAT and other taxes [2]. It is curious that, despite this clear economic sustainability even in the residential market, there is not a greater development of projects involving dry biomass.

3 National trends

According to IRENA's most recent report, in Argentina the percentage contribution of bioenergy in the generation of electricity from renewable sources in 2023 decreased by 48 % compared to 2013, even higher than the 35 % reduction recorded as a global trend for the same period [4].

It should be noted that, in Argentina, energy generation from biomass is mainly for thermal uses. However, some solid biofuels, renewable residues, bagasse, and biogas are mainly used for electricity generation, all of them in low proportions, almost insignificant compared to countries in other regions of the world [4].

According to the final WISDOM report 'Analysis of the Biomass Energy Balance in Argentina' from 2009, the national potential for dry biomass is around 37 200 kTEP, but current use is only about 5000 kTEP [5]. In addition, this analysis was updated in 2020 with the report 'Update of the Biomass Balance for Energy Purposes in Argentina,' which determined a physically and legally accessible biomass supply of 51 408 235 tons per year available nationwide, with a demand of approximately 10 131 736 tons annually.

This means that the balance between potential supply and consumption results in an annual excess of 40 421 220 tons of biomass resources available for energy use [1]. Considering that this figure does not include crop residue from extensive agricultural activities, both references show the great potential in Argentina, which is currently not being exploited, since progress is gradual and, in recent years, there is no clear trend of growth.

In Argentina, CAMMESA (Compañía Administradora del Mercado Mayorista Eléctrico SA), the Argentine Wholesale Electricity Market Clearing Company, is a private company with objectives regarding the public energy sector. It operates the Argentinian wholesale energy market since 1992 and issues regular reports regarding the national electricity sector. The most regular reports are specifically made available to the operators in the interconnected system and deal with energy dispatch, energy capacity planning, and short-term market monitoring. There are also monthly and yearly reports which are available to the public, where wholesale figures on energy consumption and generation are broken down into different categories. The information for Figs. 2-5 in this section was obtained from ten consecutive public yearly reports issued by CAMMESA, focusing specifically on renewable energy sources and, among those, on data related to bioenergy sources [6].

In Fig. 2, the total energy generated in GW·h within Argentina is itemized by source for this period. Up to and including the 2017 report, the raw "Renewables" item included only wind power and photovoltaics, and other renewable sources were detailed separately in each report; therefore, the figures for all these renewable sources were retrieved and included in the current analysis. Also as from 2018, the net imported energy was recorded in a different way in the reports; however, for all the reports under analysis, Argentina's energy imports were left out, so as to focus solely on the national energy generation sources. As a reference, a grand total of 141 398 GW·h was generated in 2023 in the country, considering all the sources [7-16].

In Fig. 3, the evolution of the percentage contribution of renewables in the total energy generation within Argentina is shown for this period.

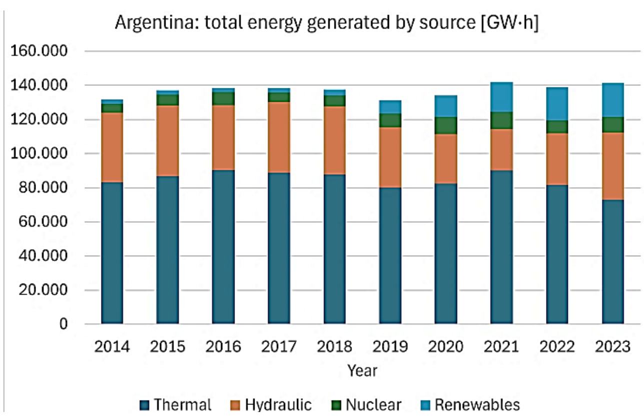

Figure 2. Total energy generated by source in Argentina [GW·h].
Source: The authors, based on public data from CAMMESA, 2015-2024 [7-16].

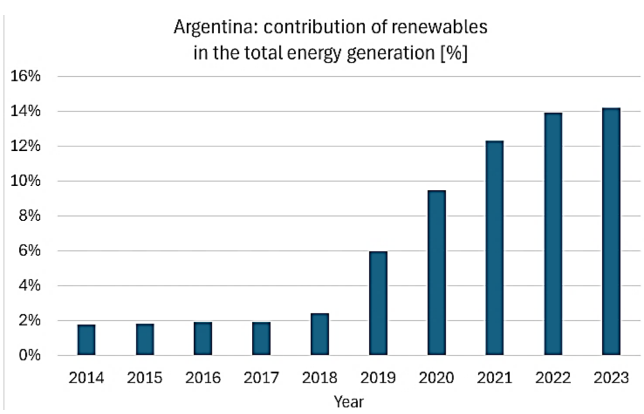

Figure 3. Contribution of renewables in the total energy generation in Argentina [%].
Source: The authors, based on public data from CAMMESA, 2015-2024 [7-16].

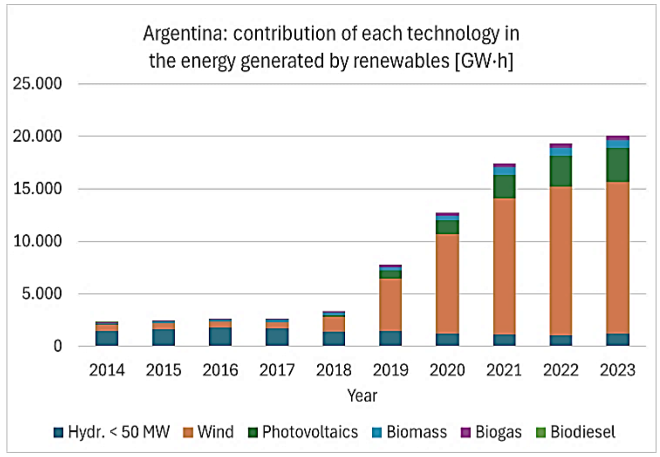

Figure 4. Contribution of each technology in the energy generated by renewables in Argentina [GW·h].
Source: The authors, based on public data from CAMMESA, 2015-2024 [7-16].

As a reference, in 2023 renewables contributed 14.20 % of the total energy generation in the country [7-16].

In Fig. 4, the evolution of the contribution for each technology in the energy generated by renewables within Argentina is shown for this period. In comparison with IRENA reports, it must be noted that CAMMESA distinguishes biomass from biogas and biodiesel, the latter being only marginal for a few years (only 2 GW·h in 2014 and 1 GW·h in 2016) [7-16].

In Fig. 5, the evolution of the energy generated using biomass within Argentina is shown for this period. As a reference, in 2023 biomass accounted for 723 GW·h of energy generation in the country [7-16].

In Fig. 6, the evolution of the percentage contribution of biomass in the energy generation by renewables within Argentina is shown for this period. As a reference, in 2023 biomass accounted for 3.64 % of the energy generation by renewables in the country [7-16].

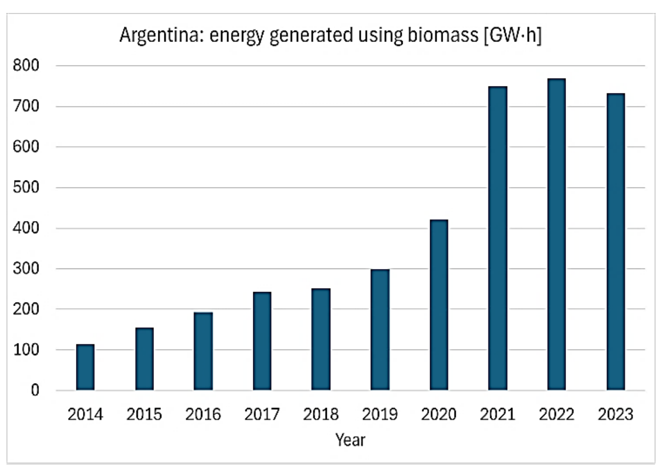

Figure 5. Energy generated using biomass in Argentina [GW·h].
Source: The authors, based on public data from CAMMESA, 2015-2024 [7-16].

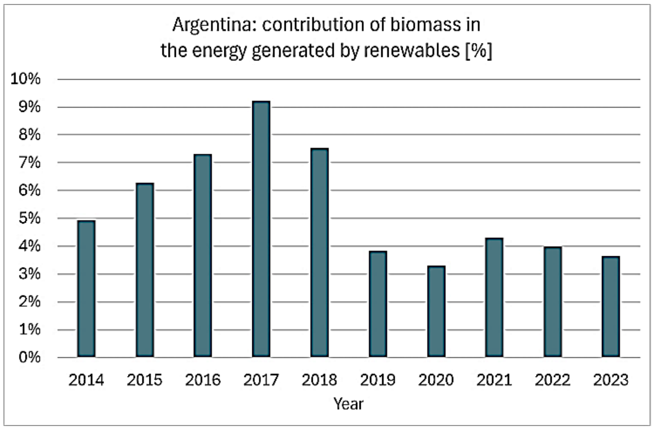

Figure 6. Contribution of biomass in the energy generated by renewables in Argentina [%]
Source: The authors, based on public data from CAMMESA, 2015-2024 [7-16].

For the 2019-2023 period, it can be seen in Fig. 6 that the percentage contribution of biomass among renewables remained at an almost constant level, 3.81 % on average. This might look incoherent with the net growth in the energy generation by biomass as seen in Fig. 5, mainly from 2020 to 2021. However, Fig. 4 helps explain that other renewable technologies, especially photovoltaics, were the ones that drove the general increase in renewable energy, which made biomass contribution remain approximately constant.

4 Regional trends

Fig. 7 highlights the three provinces included in the so-called "Región Centro" (Central Region) of Argentina: Córdoba (CBA), Santa Fe (SFE) and Entre Ríos (E.R).

Figure 7. Provinces in the Central Region of Argentina
Source: public data from website [17]

Together, in the Argentinian context, they account for 55 % of the total grain crop production, 38 % of the country's exports, and 70 % of the dairy farming.

These proportions are the main reason for considering Córdoba, one of the provinces in this region, for the analysis in this article [17].

In order to identify Córdoba in the national context regarding biomass availability balance, a piece of graphical information can be shown. As for the offer-demand balance regarding biomass for energy, Fig. 8 shows a comparative description of the overall values in tons per year for the whole country, where administrative departments account for the minimum unit of geographic division. It must be emphasized that the balance is consistently positive in most jurisdictions, and it can also be noted that the values in Córdoba tend to be around the average values for the country [18].

In addition, it is important to mention that, within the Central Region, Córdoba is one of the provinces that is most advanced in terms of energy transition regulations and policy. For this reason, the analysis in this section is mainly based on this province. In this context, CAPEC (Córdoba Advisory Council on Energy Policies) committed to working with different energy issues, including bioenergy and biofuels, achieving several regulatory advances in the province [19]. For example, in November 2020, Law 10721 on 'Promotion and Development for the Production and Consumption of Biofuels and Bioenergy' came into force, which establishes a program of encouragement, exemptions, subsidies and incentives to promote the production and consumption of bioenergy and biofuels [20].

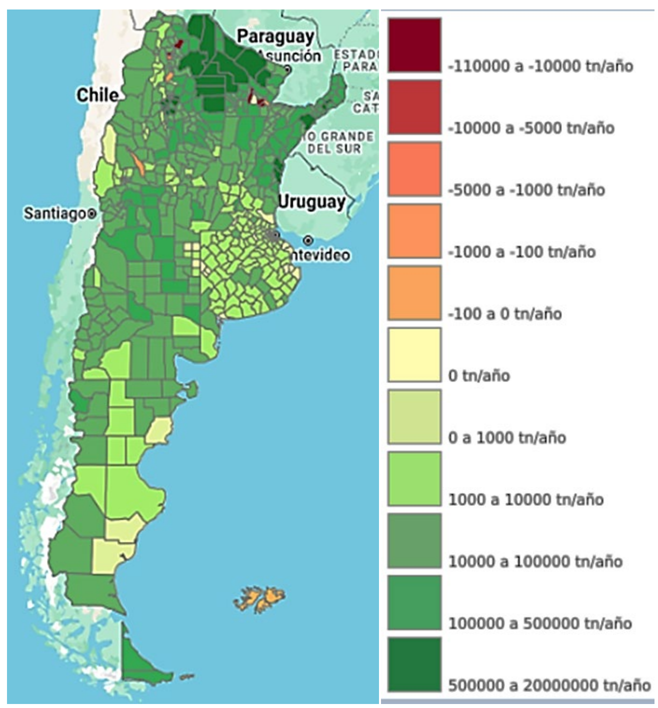

Figure 8. Balance of biomass for energy in Argentina (values in tons/year)
Source: public data from website [18]

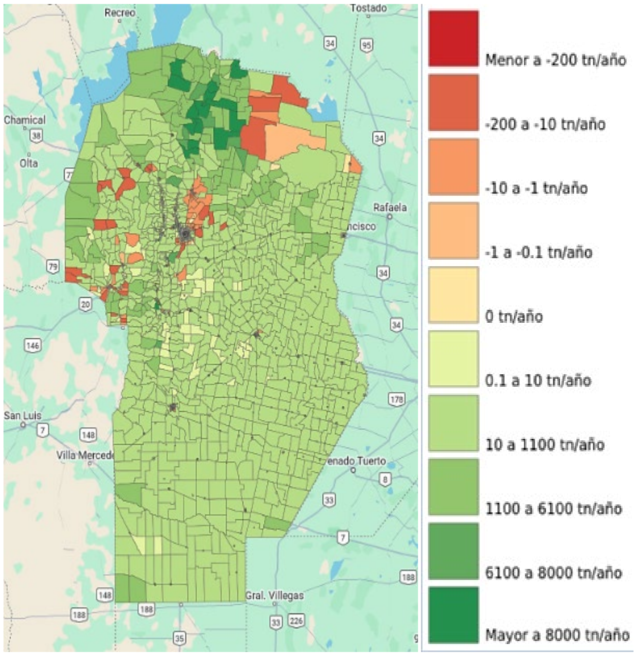

Figure 9. Balance of biomass for energy in the province of Córdoba (values in tons/year)
Source: public data from website [18]

Similarly, Fig. 9 shows the same description as in Fig. 8 in tons per year, particularly for all the departments in the province of Córdoba. These data correspond to PROBIOMASA ('Project for the Promotion of Biomass Derived Energy') whose main objective is to increase the production of thermal and electrical energy derived from biomass at a local, provincial and national level [18].

It can be confirmed that there is an overall evenly distributed positive biomass balance all over the province, which implies a considerably favorable biomass potential [18].

In terms of land cover, according to data obtained from IDECOR ('Spatial Data Infrastructure of the Government of the Province of Córdoba') more than 50 % of the area is covered by annual extensive crops: corn, soybean, sunflower and sorghum, among others [21]. This shows that several agricultural residues from different crops could be used for energy purposes.

For example, in the case of corn, which is one of the main crops, the area planted in the 2022-2023 season was 2 533 203 ha [22]. Considering that an average of 8 t/ha corresponds to corn stubble, the latter represents an interesting source of energy generation from agricultural residues. It is important to note that in recent years several producers have resorted to no-tillage as a sustainable practice. This involves direct seeding on top of the stubble of the previous crop in order to favor soil organic amendment. However, even with no-till, the soil can incorporate up to 40 % of the remaining material as nutrients, so it is possible to remove up to 25 % of the corn stubble for energy use without affecting the soil protection scheme [23]. On the other hand, in drier and colder regions, degradation processes are slower, so the accumulated stubble can interfere with subsequent planting or encourage the proliferation of pathogenic microorganisms [24,25].

In addition to crop stubble, there are different types of biomass available for energy generation [26]. There are naturally growing species such as 'espartillo' (esparto grass or *Spartina argentinensis*) or *Arundo donax*, and energy crops such as *Sorghum saccaratum* variety M81 typical of the region [27, 28], that can be exploited for energy use through different alternatives: obtaining synthesis gas (syngas) [29] for electrical energy generation, and production of hybrid pellets [23] for both thermal and electrical energy [26].

It is important to note that the biomass mentioned is lignocellulosic, meaning that it has a high lignin content, which is associated with a good calorific value for both syngas and pellets.

However, despite the large biomass availability in the province, the electrical energy generation facilities are very scarce: CAMMESA identifies only three biomass-based thermal plants in the province of Córdoba. The following are the nominal powers and locations of said power plants: 9 MW in General Cabrera (Prodeman SA), 3 MW in Ticino (Ticino Biomasa SA), and 0.5 MW in Las Junturas (Emerald Resources SRL). As a reference for 2023, the plant in General Cabrera produced 50.9 GW·h and the one in Ticino generated 22.8 GW·h; no generation records were found for the plant in Las Junturas. Together, they add up to 73.7 GW·h. Comparing this with the information in Fig. 5, it can be seen that Córdoba supplies only 10.19 % of the total biomass energy in the country. Taking into account the agricultural resources in the region, it could be suggested that this contribution could be increased remarkably [6].

5 Discussion

Due to Argentina's favorable agro-ecological conditions and the competitive advantages of the agricultural sector, it can be confirmed that the country has a huge potential regarding energy generation with biomass. However, this has still not been leveraged on a large scale, even though there are several regional or provincial initiatives and policies promoting the use of biomass for energy purposes.

Currently, there are some technical, economic, legal, institutional, and sociocultural barriers and challenges that need to be overcome to increase the share of bioenergy in the national energy matrix [30]. The proliferation of biomass as an energy resource must involve a productive strategy that is attractive to producers. Currently, the profitability from traditional crops in the region is high, so the introduction of new species should be economically competitive with the production of commodities. On the other hand, the demand for solid fuels in the country for energy production is, at best, limited, so the production of pellets or briquettes involves costs and logistics that producers are not willing to adopt unless justified by the demand. Successful experiences in generating electrical energy with dry biomass emerge as a solution to disposal problems involving peanut residues, at the same time providing a solution to local grid power quality issues. However, for the typical crops in the region explored in this work, crop residues do not cause any such problems, making them unattractive for added-value generation. In this context, producers lose interest in energy generation because the economic competition is not only against the replacement of fossil fuels but also against the profitability of other crops [30]. However, local energy production brings other benefits into focus, such as energy self-sufficiency, decreasing grid demand, adding value to crop residues, developing skilled labor, and creating job opportunities. It would be inadequate to attribute to producers the responsibility of diversifying the productive matrix over the profitability of their agricultural businesses. Therefore, it may be necessary to discuss cross-sectoral policies that promote the continuous and long-term development of the biomass sector. This includes energy strategies that create an attractive market for fuel production and encourage the incorporation of sustainable and distributive economies [31], based on technological development and economic growth [32]. Such strategies should integrate energy-vulnerable communities, generate new job opportunities, and attract investments that add value to residues through new business ventures.

Energy derived from biomass is of particular interest because it helps protect the environment by reducing greenhouse gas emissions and converting waste into resources. Additionally, it provides a storable fuel that can be used with existing generation technology in thermal power plants with minimal modifications. This presents an interesting possibility in this stage of energy transition, with the additional possibility of supplying thermal needs for domestic heating mainly in areas distant from population centers, with no accessibility to the gas network. While this alternative is viable and is already exploited in European countries, it still needs to be explored in Latin America, and specifically in Argentina. To this effect, resources should be managed applying comprehensive, long-term energy transition policies with sustainable criteria and a focus on the profitability of the agricultural sector and a socio-productive perspective. This approach would benefit rural communities, protect productivity, and ensure resource conservation to support energy independence.

6 Conclusions

In recent years, according to international reports, Argentina follows the global trend of slow or almost zero growth in the use of biomass for energy. This situation is replicated in the specific context of Córdoba, one of the three provinces of the so-called Central Region, despite its great availability of biomass, wide variety of agricultural production, and favorable regulations for the generation of energy with regional biomass. It is evident from the literature that projects using dry biomass are very limited in quantity and scale in the mentioned province of Córdoba. Besides, an analysis on previous studies including those conducted by the authors on energy applications of examples of regional biomass such as sorghum, 'espartillo' (esparto grass), or corn, demonstrates that dry biomass resources are very poorly exploited for energy generation in the selected province. Considering all the above, it becomes evident that there are still several technical, economic, legal, and especially local sociocultural challenges impacting the advancement of this type of energy.

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A.L. Quicchi, received the Bs. Eng in Chemical Engineering in 2019. She is an Assistant Professor both in Calculus II and in Thermodynamics and Thermal Machinery in the San Francisco Regional Faculty of the UTN (Universidad Tecnológica Nacional) in Argentina. She is currently pursuing her PhD in Industrial Engineering at the Santa Fe Regional Faculty of UTN. She also works in the biomass area of the UTN R&D group CIDEME in her Faculty.
ORCID: 0000-0001-6369-1046

M. Bernard, received the Bs. Eng in Chemical Engineering in 2010 and the PhD in Chemical Sciences in 2020. She has worked in several research programs and projects related to biomaterials with several applications, and in the last few years turned her focus to energy efficiency and biomass for energy generation, with emphasis on gasification of regional materials. She is currently a tenured full-time Research Professor in Thermodynamics in the San Francisco Regional Faculty of the Universidad Tecnológica Nacional (UTN) in Argentina and coordinates the biomass area of the UTN R&D group CIDEME in her Faculty.
ORCID: 0000-0003-2525-9089

D.M. Ferreyra, received the Bs. Eng in Electromechanical Engineering in 2001, the MS degree in Engineering Sciences with a mention in Electrical Engineering in 2014, and the PhD degree in Electrical Engineering in 2018. After working for several years in metalworking and electromechanical companies, he developed his university career and is currently a tenured full-time Research Professor in Electrical Machinery in the San Francisco Regional Faculty of the Universidad Tecnológica Nacional (UTN) in Argentina. There, he has worked in several R&D projects related to electrical machines, power quality, energy management, and distributed generation using renewable sources. He is currently the Director for the UTN R&D group CIDEME in his Faculty.
ORCID: 0000-0003-2251-2819

G.A. Schweickardt, received the Bs. Eng in Electrical Engineering in 1989 and the PhD degree in Engineering/Energy Economics in 2002. He also obtained an MS degree in Energy Economics and Environmental Energy Policy in 2005, as well as different SP degrees in Environmental Impact Assessment, Energy Economics, and Software Engineering-Data Science. He is a Senior Researcher for the National Scientific and Technical Research Council (CONICET), Argentina. His research interests include energy economics, computational artificial intelligence, soft computing optimization, renewable energies, distributed generation, smart grids, and electrical power distribution systems planification and operation. As a Professor in the Concepción del Uruguay Regional Faculty of the Universidad Tecnológica Nacional (UTN), he is the Director of the Research Group on Computational Economics of Regulation and Renewable Energies (GIECRRER), and the Director of the Master Program in Renewable Energies.
ORCID: 0000-0002-0843-2946