Economic incentives and energy production from forest biomass in Argentina[1]

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Abstract

Argentina faces a double challenge: on the one side, to support and strengthen the economic development process with the enlargement and enhancement of the energy matrix; and on the other side, the country adhered to the global trend of stimulating the development of renewable energies. It is there where the potential of non-conventional renewable energy (NCRE) especially stands out, and dendroenergy in particular.

In order to stimulate bioenergy production from *ad hoc* forest plantations as well as by using forest by-products, it is essential to have a distributed generation regulatory and operational framework, or otherwise to work on a logistic profile that matches supply and demand (industrial and household) for energy, also considering power generation as well as preferrably cogeneration schemes. From a regulatory point of view, Argentina is already on its way towards such a system. The second item implies deeper planning policies, in a longer term.

Even though a dynamic NCRE development has been seen for the past few years, dendroenergy projects in particular are below the identified potential. Drawing mainly on the INTA-FAO-Probiomasa consultancy (FAO, 2020a) precedent, this work discusses the identified areas with the greatest dendroenergy potential, the current institutional and regulatory incentives, and the necessary economic requirements for dendroenergy capacity growth.

Key Words: dendroenergy, biomass, forestry, economic incentives, renewable energy sources

Resumen

La Argentina enfrenta un doble desafío: por un lado debe acompañar y fortalecer el proceso de desarrollo económico con el crecimiento de la demanda y la complejización de la matriz energética; y por otro, el país adhirió a la tendencia mundial y se comprometió a favorecer el desarrollo de las energías renovables. Allí, se destaca especialmente el potencial de las no convencionales (ERNC) y, en particular, la dendroenergía.

Para estimular la producción de bioenergía, tanto a partir de implantaciones boscosas *ad hoc* como mediante la utilización de residuos o subproductos forestales, resulta esencial contar con un régimen normativo y operativo de generación distribuida, o bien un perfil logístico que calce oferta con demanda, tanto industrial como domiciliaria, y tanto en generación eléctrica como preferentemente en esquemas de cogeneración. Desde el punto de vista normativo, la Argentina ya está transitando hacia un sistema acorde. El segundo elemento se inscribe en políticas de planificación más profundas, con un horizonte más largo.

Si bien el desarrollo de ERNC en los últimos años se muestra dinámico, los proyectos de desarrollo dendroenergético en particular están por debajo del potencial identificado. Partiendo del antecedente de la consultoría INTA-FAO-Probiomasa, el presente trabajo expone las zonas con mayor potencial dendroenergético, los incentivos vigentes, y qué condiciones económicas son necesarias para lograr un crecimiento en la capacidad dendroenergética.

Palabras clave: dendroenergía, biomasa, forestales, incentivos económicos, energías renovables

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1. Introduction

Argentina faces a double challenge: on the one hand, it must support and strengthen the economic development process with demand growth and the expansion and enhancement of the energy matrix, and on the other hand, it must encourage renewable energy development, a global trend that the country has been adopting. The potential of non-conventional renewable energy (NCRE) sources, particularly dendroenergy, stands out in that respect.

Dendroenergy is the production of energy by thermoelectric transformation of woody biofuel from forests. This is a particularly interesting alternative to profit from biomass energy, because it makes it possible to fulfill several goals at the same time:

- Using waste and byproducts from the various stages of the forest industry chain that have zero to residual monetary value (and which are a potential environmental liability);
- Using and combining those residues and byproducts in wood specifically produced for energy purposes;
- Supporting the transition towards a green economy (bioeconomy) by helping to minimize fossil fuels dependence with no pressure on the food system, since these crops are particularly grown on non-agricultural soil, with less edaphic suitability requirements;
- Distributing geolocalized energy generation in a supplementary manner to other territorial territorial coverages, such as potential suitability for wind, solar and small scale hydroelectric energy;
- Combining the energy use structure with other biomass sources and the transformation process to cogenerate other types of energy, thus increasing the efficiency level;
- Reducing several types of pollutant emissions;
- Reducing the risks of wildfires, as well as plagues and diseases resulting from biomass accumulation on the land;
- Growing forests on lands that are used for less preferable purposes or subject to degradation;
- Untying energy costs from imported fuel price fluctuations;
- Creating new economic opportunities for rural areas.

The Food and Agriculture Organization (FAO) of the United Nations has especially weighed the externalities of dendroenergy production, as compared with other renewable energy sources (e.g. solar and wind energy) with a currently lower market cost (FAO, 2020b). The FAO Report particularly highlights socio-economic externalities which are “an indirect and induced consequence of investment, employment and taxes”, in addition to environmental benefits and, particularly, a set of non-monetized, although featured, externalities that are included in such report, such as the recovery of landfill sites, avoided costs associated with fires and pollution, and the multiple derivations of distributed generation.

The above mentioned characteristics of this specific type of energy use make it an energy policy goal to be considered within the portfolio of available technologies and in the NCRE category, for which a special level of incentives is foreseen.

Now, in order to foster bioenergy production from *ad hoc* forest plantations and using forest waste or byproducts, it is essential to have a regulatory and operating framework for distributed generation, or a logistic profile at district level to adjust supply to both industrial and residential demand. In other words, forest biomass is either used directly for energy-related purposes in the areas where it is mostly required, i.e. energy supply is adjusted to demand, or production becomes geographically independent of consumption by using the potential for distributed generation by means of the Argentine Interconnection System (SADI, for its acronym in Spanish).

The idea that energy supply should be geographically adjusted to demand has to do with a set of major in-depth, long-term policies which should be necessarily linked to many other territorial planning dimensions, going beyond the discussion about the role of the State in such potential course of action. However, either as an alternative or a supplement, the immediate option for this complex challenge is distributed generation regulation and promotion, and Argentina is already following this path in terms of rules and regulations. At present, the specific instruments setting forth a regulatory framework for this type of contribution to the national energy matrix are Law No. 27,191, its applicable Regulatory Decree No. 531/16, as amended, and other resolutions and provisions mainly issued by the relevant enforcement authority, whereby the provisions of the reference rule are made operative.

Like any other biomass energy source, dendroenergy can be produced by secondary use, i.e. the use of byproducts or waste, or from primary biomass produced following an energy-related objective, i.e. an *ad hoc* energy-related forest plantation in this case. We can see that, in Argentina, the secondary use is being currently developed, whereas the primary component has not been explored very much yet. Even though a dynamic NCRE development has been seen for the past few years, dendroenergy projects in particular are below the identified potential.

Drawing mainly on the INTA-FAO-Probiomasa consultancy (FAO, 2020a) precedent, this work discusses the identified areas with the greatest dendroenergy potential, the current institutional and regulatory incentives, and the necessary economic requirements for dendroenergy capacity growth.

2. Dendroenergy Potential

All forest plantations and all specific production activities have geographic determinants and limitations according to the pursued objectives, their impact, legal restrictions, etc. The following technical zoning criteria for potentially suitable areas for forest plantation development to produce biomass for energy purposes in particular stem from the INTA report (2016) coordinated by R. Fernandez and A. Lupi under the INTA-FAO-Probiomasa consultancy project. The maps created and the relevant area calculation by F. Navarro de Rau have been published by FAO (2020a), including each and every detail. In this paper, however, we only sum up the final results.

Such report identified the main characteristics that any area or region must have for potential dendroenergy plantations. It states that there are environmental and legal restrictions which create areas where it is not possible or advisable to recommend establishing this type of plantations, including:

- Climatic restriction due to water risk: The availability of water is one of the main limiting factors for the development of dendroenergy forest plantations. In this context, it is considered that areas with less than 800 mm annual rainfall and negative or neutral water balance should not be used for this purpose, since species productivity shrinks to levels that do not warrant cultivation, in addition to their potential negative environmental impact.

- Soil capability: Class I, II or III lands, as classified according to the USDA taxonomy system based on a soil capability survey (Klingebiel and Montgomery, 1961), are considered agricultural lands and, therefore, they are excluded as potentially suitable for forest plantation. Class VIII lands (soil limited to conservation practices) are also excluded.

- Legal restrictions: National Law No. 26,331 about Minimum Budgets for Native Forest Environmental Protection, enacted in 2007, sets forth three native forest conservation categories. According to this law, no changes can be made to soil use on lands with forest areas classified by provinces as Category I (red) and Category II (yellow) under each province's land use planning. Therefore, exotic, high-growth species plantations are not allowed on such lands. Lands of high conservation value, such as RAMSAR sites, biosphere reserves, and protected areas at the national and provincial level, have also been excluded.

Four forest macroregions in Argentina were considered, as well as the following possible crops (species or genuses) for each region:

- Mesopotamia: *Pinus taeda*, *Eucalyptus grandis*.
- Northwestern Region: *E. grandis*, *E. camaldulensis*.
- Pampas Region: *E. camaldulensis*, *E. viminalis*, *E. dunni*, *Salix,* and *Populus*.
- Central Region: *E. grandis*, *E. camaldulensis*, *E. tereticornis,* and *E. viminalis*.

The Paraná Delta, which was originally included in the Pampas macroregion, was not considered in the soil suitability maps, due to the lack of maps allowing us to conduct an edaphic constraint analysis. Furthermore, the Patagonia region was excluded from the analysis, because the first report in 2016 concludes that the crop is not feasible for specific energy purposes, basically due to long crop rotation periods. With these two exceptions, the above mentioned geospatial analysis was conducted for the rest of the forest regions in the country, eliminating any ineligible area and classifying the remainder by suitability level, taking into account the specific requirements of the various forest crops included.

The forest yields we considered are within 15-45 $m^3ha^{-1}yr^{-1}$, and they are discussed in the full document by region and forest genus (*op. cit.*), also including the relevant detailed maps. They arise from historic data, estimates and field measurements of the knowledge network field trials of INTA's forest program at the time the reports were written.

Region	Mod. Suit. Area (ha)	Full Suit. Area (ha)	Total Area (ha)
Pampas	6.398.524	1.383.322	7.008.254
Mesopotamia	4.744.444	631.019	5.375.463
Central	2.437.900	106.157	2.544.057
Northwestern	325.104	-	325.104
Total	13.905.972	2.120.498	15.252.878

Table 1: Suitable areas for forest biomass cultivation by macroregions. Adapted from: FAO (2020a).

The maximum potential surface areas to produce forest biomass for conversion into electrical power in Argentina are quantified in Table 1, making a distinction between moderate suitability (with reduced production conditions), and full suitability. On average, the production yield in moderately suitable lands is 20% lower than in fully suitable ones.

In order to energetically measure this potential, if we consider a conservative general average yield —both in terms of production and environmental impact— for all the regions and forest species, the maximum biomass production possible is estimated and the mean conversion rates in power stations of different sizes are applied; its transformation into electrical power would result in over 10,000 MW of installed capacity. (This figure gives an idea of the generation level. We are not seeking accurate projections, since they would require an in-depth geographic analysis and this is beyond the scope of our goals.) This accounts for approximately one fourth of the current total installed power generation capacity at the national level. (According to the CAMMESA [Managing Corporation of the Wholesale Electricity Market], the installed capacity in July 2020 was 40,452 MW, with a historic maximum effective capacity of 26,320 MW.) We should remember that such values are obtained by exclusively measuring the potential for dedicated bioenergy forest plantations, i.e. without including sustainable biomass extraction from natural forests, the use of forest industry byproducts and waste, or other sources.

According to the technical document presenting the updated national bioenergy balance recently published in the context of the “Project for the Promotion of Biomass Energy”, native forests, forest plantations and sugar cane crop are right now the main sources of direct biomass supply for energy purposes (FAO, 2020c). Firstly, this document presents estimates of potential direct biomass supply for energy purposes according to the different supply sources available in Argentina. Secondly, the estimated direct supply is weighed according to physical and legal accessibility, limiting it according to communication channels, physical characteristics of the land and legal extraction restrictions, in order to assess the accessible direct supply.

According to report estimates for direct biomass supply based on pruning and thinning, and forest plantation harvesting residues, forest plantation crops represent the main supply of biofuels. Potential biomass climbs to 4,669,692 t/year (43% of total supply), whereas the estimated accessible supply was 3,246,864 t/year. At this point, it is important to highlight that supply is mainly located in the provinces of Misiones and Corrientes, concentrating 75.7% of the dry biomass of forest crops.

However, if we also consider potential forest industry indirect supply, byproducts and/or waste (slabs, pollarding, shavings, sawdust, barks, and chips), we should take into account a volume of 6,258,719 m^3 of wood residues per year, which are equal to 3,129,360 t/year of biomass (FAO, 2020c). It is undeniable that, at present, there is also geographic concentration in the location of indirect supply (61% concentrates in the provinces of Misiones and Corrientes), since the forest industry is set up near forest plantations due to the large volumes of raw material to be transported and the resulting high logistic costs.

The results obtained for natural forest woody biomass estimates are also shown in this way. The supply of biomass with bioenergy potential from native formations climbs to 73,010,007 t per year, although the reported accessible volume, with no legal restrictions and which meets the physical accessibility criteria, was 32,800,764 t/year (*op. cit.*). This type of resource is mainly available in the northern area of the country (Salta, Chaco, Santiago del Estero, Formosa, and Misiones).

At present, bioenergy potential is an issue that arouses the interest of political and economic decision makers, as well as the academic and institutional arena. For instance, Manrique (2020) provides an updated and complete outlook of the cases under development in this sector across the country, for all power generation using biomass, from a point of view that differs from that of official entities. This work does not only present the latest quantitative and qualitative progress in the development of this sector, but also a few critical aspects to consider, such as the high level of imports in the investments made, and regulations still missing in terms of environmental safeguards.

Furthermore, FAO (2020d) published a report describing different specific experiences in the development of biomass-based bioenergy projects, which are at different development stages and represent different profiles. Regarding forest biomass projects, the report presents the results of interviews in the following cases: Pindó Ecoenergía, Zeni, Fresa, and Molino Matilde Bioenergía.

Pindó Ecoenergía is a cogeneration plant which operates using industrial sawmill byproducts (bark from roundwood, wood chips, sawdust, planer shavings, etc.). This plant is located in Misiones, and all the biomass is self-supplied from their own forest plantations and their industry. The project consists of a cogenerator which produces power and steam used in the industrial process. Self-generated installed power capacity is 4 MW, with a 2 MW grid supply agreement and a power demand of approximately 1.7 MW from the industrial plant. The investment climbed to USD 7.5 million (FAO, 2020d).

The main factors that were identified as limitations are financial restrictions (access to financing due to the large investment amounts), uncertainty regarding the sale of energy through government-regulated bidding processes, and a currency depreciation in between which directly impacted the acquisition of imported equipment. In addition, there are technical aspects, e.g. outages, which prevent supplying contractual power capacity into the grid. Approximately 90% of outages occur due to grid failures beginning on the second year of operation.

Zeni is also a cogeneration plant in its planning phase and expected to be set up in Esquina, Corrientes. The project proposes to install a plant with 8-10 MW power capacity: 3 MW for self-consumption and 5-7 MW for sale to the Argentine Interconnection Power System. The plant would be supplied with pine residues (dry and wet sawdust and dry and wet chips) and would require 6,000 t per month. This amount is currently deemed available. Moreover, it could be eventually fed with fine thinning from its own plantations. The investment in this project is estimated to be approximately USD 35 million, but the decision to execute the project has not been made up so far.

The reasons for project suspension are, in part, risk aversion in business people, uncertainty about the availability of the biomass volume that the plant would consume in the long term, due to the potential added value of wood residues that would compete with the energy production purpose, and investment volume, which is extremely higher than the amount invested to date. The fact that this activity is highly regulated by the State is also clearly identified as a source of uncertainty.

Fresa is a forest biomass electricity generation project which is different to the above mentioned initiatives, since the purpose is not full self-supply of the bioinput. Supply sources include: forest biomass from own plantations (20%), residues from biomass of sawmills that are near the project site (35%), and wood chips produced in the area (45%). This project is located in Gobernador Virasoro, Province of Corrientes, and a power plant with 40 MW installed power capacity is expected to be set up, with capacity to supply the Argentine Interconnection Power System with approximately 36 MW (*op. cit.*). The projected investment is USD 55 million. The main barriers identified in this case are associated with bureaucratic and regulatory obstacles, particularly regarding the power purchase agreement.

Molino Matilde Bioenergía, instead, is an intermediate case and it is located in Cerro Azul, in South Misiones. The projected installed power capacity for the plant is 3.3 MW, selling 3 MW to the electricity grid and generating energy from *eucalyptus* and pine byproducts. The plant will be supplied with residues from sawmills that are near the project site: 21,000 t of biomass, 45% of the total biomass it requires, ensuring long-term (20-year) agreements with the forest industry; and also forest biomass that will be obtained from own forest plantations, adding 32,000 t per year during the project commercial stage. The estimated investment is USD 7.3 million and the financial barrier was identified as the main limiting factor. Those who are responsible for the project underscore the funding access restrictions and the sudden interest rate increases they had to face at the beginning of the project.

Generally speaking, the FAO report (2020d) concludes that one of the main reasons to develop energy generation projects is related to the needs of the industry itself, either to ensure increased capacity and energy to support a growing industrial demand, or to mitigate environmental liabilities. The report also highlights the need to encourage thermal energy supply projects, which currently have no specific benefit.

Rounding up, we will review the list of projects that are currently effective under the Argentine Program for Electricity Supply Using Renewable Sources (RenovAR), a few active ones and others which are under way or have been interrupted. These projects constitute the leading edge to develop Argentina's dendroenergy potential. To date, eighteen biomass energy generation projects have been awarded in calls for bids (rounds 1, 1.5, and 2), ten of which are based on forest biomass. Only one of them is fully active and belongs to the first round. It is the Pindó project, located in Misiones, with a hired capacity of 2 MW. The other projects are either under construction, in the planning phase or, in a few cases, they have been called off for the time being. Hired capacities range from 2 MW to 37 MW, and the agreed prices vary from USD 108 per MWh to USD 143.10 per MWh, taking into account all the additional incentives under current rules and regulations (Ministry of Energy and Mining [MEM], 2020a and 2020b, and current resolutions).

By way of reference, the weighted average price for the 147 projects awarded under the RenovAR Program for the different energy sources is USD 54.72 per MWh. This price is pushed below the prices for biomass in wind and solar photovoltaic energy projects, which are currently the most competitive ones from a financial point of view. As a comparative parameter at the international level, for Lazard (2017), the usual biomass energy production costs for 2017 were USD 55-114 per MWh. Later on, this item was discontinued in the 2018 and 2019 reports (Lazard, 2018 and 2019). According to this source, projects using other energy sources under the RenovAR Program are competitive at an international level.

3. Political and Regulatory Framework

To get a clearer picture of the political and regulatory framework regarding dendroenergy, we should start by identifying the initial problem and the resulting political objective of transformation. The Argentine energy matrix is highly dependent on the use of fossil fuels. More than 86% of the energy consumed in the country is still obtained from fossil fuels, which are considered non-renewable resources. This proportion is greater than the average rate in the Latin American matrix and the current worldwide mean rate (Altomonte, 2017; Pellerin-Carlin, 2017; Fernández, 2019).

Energy Sources Share (%) in 2018	
Natural Gas	58,4
Petroleum	27,7
Hydroelectricity	5,3
Renewable	**5,0**
Nuclear	2,3
Carbon	1,4

Table 2: Current national energy matrix. Adapted from: SSPE-Secretaría de Gobierno de Energía, Mastronardi et al. (2019)

According to reports developed by the Argentine Ministry of Energy, CAMMESA and other related agencies, the share of renewable energy sources in the energy matrix has been growing over the past few years as compared with the country's total demand. Such share was 6.1% during 2019, and we observe that it is around 8% of the total demand according to the latest data published so far, dated July 2020.

RENEWABLE [GWh]	jan/dic-19	jul-20
Renewable HYDRO	1.462	59
EOLIC	4.996	766
SOLAR	800	67
BIOMASS	299	44
BIOGAS	256	28
TOTAL RENEWABLE	**7.812**	**964**
TOTAL DEMAND	128.905	12.178
% Share REN/DEM	**6,1%**	**7,9%**

Table 3: Current renewable sources share in the national energetic demand. Adapted from: CAMMESA (2020a) y CAMMESA (2020b).

In spite of a relative profile improvement in the last few years, this energy composition generates significant carbon dioxide emissions, due to the existence of a large amount of fossil fuels. This contributes to the global warming process, in addition to other related forms of pollution. Even though Argentina's contribution to the global warming process is, because of the size of its economy, much lower than that of other nations with bigger economies, the performance of Argentina in this respect is, nevertheless, noted, and it cannot be separated from the country's political insertion worldwide. Argentina has endorsed the multilateral political initiatives for carbon reduction and energy transition, in the context of the G20, by means of the 2015 Paris Agreement, as well as other framework instruments. In this scenario, and considering the global trend towards designing and implementing actions to mitigate the causes of the so called "global warming", focusing on carbon dioxide emissions, Argentina followed suit by taking measures intended to change the composition of the domestic energy matrix, to the detriment of fossil fuels and encouraging a more relevant role of NCRE sources.

NCRE sources are those that are not used up or exhausted during useful energy transformation and use processes, and, at the same time, have a significantly lower environmental impact than the rest of the renewable energy sources. Wind energy, solar photovoltaic energy, hydroelectric energy generated in small scale power plants (up to 50 MW in Argentina, although the criteria may vary across countries), and biomass energy are the main components of NCRE sources. Hydroelectric energy is usually the main component excluded from this group in big infrastructure works, due to its environmental and social impact.

With the 2015-2016 change of political cycle in the national government, a gradual tariff structure readjustment process was mandated in the energy sector. At the same time, the expansion of renewable energy sources was encouraged pursuant to Law No. 27,191, which was enacted a few months before the change of administration, but was regulated by Decree No. 531/16 at the end of March, 2016. Such law sets targets for increasing the NCRE share in the entire national power supply system, which should climb from 8% of the total supply in 2017 to 20% by 2025. These targets mean that NCRE generation capacity will be 17 times higher in a decade. Different agents in this sector consider this is an ambitious goal.

Nevertheless, a prospective energy exercise conducted by non-governmental organizations and business chambers shortly before the law was passed, set out much more optimistic potential scenarios for the development of NCRE sources (Fernández, 2015). According to the exercises made for those scenarios, some participants considered that the share of NCRE sources under BAU (*Business As Usual*) conditions could account for 57% of the wholesale electricity market (WEM), whereas in energy efficiency rational use of energy (RUE) scenarios, such share could rise to 67%. However, the average rate in both scenarios was lower: 33% and 35%, respectively. Specifically, biomass energy scenarios are very heterogeneous, ranging from 0.3% to 33% of total NCRE, with an average of 9.7% (*op. cit.*). It is worth noting that the issue of using wood industry residues was discussed in those analyses, but the biomass that would eventually originate in *ad hoc* forest plantations was not considered.

Therefore, drawing on the idea that NCRE development is a political objective and that it is still below its potential level, we may wonder what causes this gap. In this respect, we have found the following elements that help us understand the conditions that shape the background of this development, by following and updating the FAO report (FAO, 2020a).

The series of national laws passed since 1998 —Law No. 25,019, 26,190, and 27,191— and the confusing collection of supplementary regulations —Resolution No. 1281/06, 220/07, 280/08, 712/09, and 108/11, among others— failed to create a regulatory framework to facilitate the development of NCRE sources. On the contrary, the approval of tools to promote such sources of energy, which were not set in motion, did not work properly, or were not fully implemented, resulted in an unfavorable scenario for private investment in this sector. After the regulation of the renewable energy law which is currently in effect, the implementation of the RenovAR Program was an attempt to correct the above situation.

Moreover, several Argentine provinces have enacted their own regulatory frameworks for NCRE promotion and development. Even though they are not mutually comparable in all cases, most of them adhere to Law No. 26,190.

The regulatory framework which is currently in force ratifies the need to increase the share of NCRE in the Argentine energy matrix, raising the matrix share increase target to 20% by 2025. A new aspect compared with previous schemes is that all large users of electrical power (those demanding over 300 kW) will need to meet that target on an individual basis. To observe this rule successfully, those large users may self-generate their own energy, or purchase the electricity generated using NCRE sources from a distributor such as CAMMESA for a cap price of USD 113 per MWh. It should be noted that, even though this price is higher than the conventional energy market price, it is lower than the subsidized price for which the system purchases energy of this type under RenovAR bids (including the additional incentive amounts for small-scale generators, etc.).

The current law also sets forth a series of fiscal and financial benefits that are intended to encourage investment in electricity generation from NCRE sources, including tax benefit regime, specific fiscal credit, special import duties, and the creation of a specific fund for the promotion of renewable energy sources.

The tax benefit regime consists of the advance refund of the Value Added Tax (VAT) and accelerated depreciation for Income Tax purposes regarding the execution of civil engineering works, the acquisition of capital goods and other investments in new plants or the expansion of existing ones. These benefits are not mutually exclusive and apply to the purchase of national and foreign personal property.

For investment projects with a proven 60% of domestic content in electromechanical facilities, excluding civil engineering works and with a few exceptions and justified variations, beneficiaries are expected to receive a tax certificate they may use to pay domestic taxes. The certificate is equal to 20% of the value of the domestic content in electromechanical facilities.

Regarding special requirements to import machinery, an import duty exemption applies to the import of capital goods and equipment parts or pieces to be used in projects for power generation from renewable sources, provided that they are not manufactured locally.

Finally, the Fiduciary Fund for the Development of Renewable Energy Sources (FODER, for its acronym in Spanish) implies the creation of a specific trust for easy access to funding for renewable energy projects. This trust has been formally active since 2017. The funds may be allocated to grant loans or make capital contributions, provide sureties and guarantees to support energy purchase agreements executed by CAMMESA, subsidize the financial cost of loans for renewable energy projects, and also make direct contributions to funds for financing those projects. In dendroenergy projects, FODER has been playing a prominent role as a guarantee fund, rather than a direct financing entity.

Another key regulatory framework item, which is not fully in effect yet, is the authorization for distributed generation (DG) from NCRE sources, generally in cogeneration cycles (heat-electrical power). This system allows using the generation potential of this type of energy sources developed at small and medium scale.

DG adds a new agent to the power generation, transmission, distribution and consumption scheme: the prosumer, i.e. an electricity consumer who also produces and sells power generated from NCRE sources. This means that energy flows are bidirectional. Therefore, to manage such flows, demand monitoring stations need to be set up at certain points of the grid, including sensors to measure each local flow and determine any failures that may occur in that grid.

The management of such grid implies adjusting consumption with power generation, and this leads to the need for reform of the regulatory framework for the Argentine electricity market, which was legally structured in the 1990s. This structure determines that power generation is a public good of interest, while energy distribution is a public utility due to its natural monopoly characteristic.

One possibility to reconcile both legal conditions is the emergence of a trader, i.e. an agent that would acquire the energy generated by the prosumer in order to sell it to CAMMESA or to the specific spot market for each type of technology. For the transmission of the energy to be traded, such agent would offer a tariff compensation to distribution companies in order to cover the value added by distribution (VAD, for its acronym in Spanish).

As for the price of the energy generated and sold by prosumers, the proposals focus on two alternatives: net metering and net billing. Net metering considers the energy generated and fed into the grid by a prosumer, which is then deducted from the consumed energy. The resulting balance is multiplied by the energy price in order to determine the tariff to be paid by the prosumer. Experts agree that the key to this system is the time period considered to measure the balance, because the result will change if it is measured on an hourly or a monthly basis, for example.

The second scheme —net billing— consists in estimating the monetary value of the energy generated and consumed by a prosumer, in order to determine the difference between both amounts later and show the final tariff. The most developed case of this model since 2014 has been Chile, and with initially positive results (Altomonte, 2017).

Another key aspect of DG is incentives to prosumers (feed-in tariffs), i.e. the differential prices paid to prosumers for their generator role, so that they may recover their advance investment within a shorter term, thus making it a more appealing option against other alternatives. These incentives are necessary when there is no grid parity, i.e. when the cost of taking energy from the power grid is lower than the generation cost for a prosumer. Therefore, these special incentives must be applied according to calculation and cost allocation criteria, reviewing them regularly, which will later lead to an alignment involving a convergence price allocated by the market. If these incentives are kept for a long time and they are not reviewed regularly, different types of inefficiencies may occur.

DG allows making good use of the potential of renewable sources at small and medium scale, reducing the demand for generation from big production sites (thermal power plants using fossil fuels or hydroelectric power plants), and making the distribution system more efficient by balancing demands and decreasing losses due to long-distance transmission. There is a general consensus that DG based on NCRE is associated with a rational use of the energy policy, and it is essential when it comes to designing an energy scenario with increasing NCRE weight.

To sum up the regulatory, political framework for dendroenergy in Argentina, it can be said that, even though the country has been building a modern system in line with the pursued objectives based on the multilateral political insertion profile, which is surviving the changes in the domestic political cycle, at least for now, the development level of such system is still insufficient to take a qualitative leap towards a fully functional and operational scheme regarding its differential attributes. There is still a long way to go to improve the distributed generation scheme. This advancement reinforces and strengthens the incentives that are already in force.

Another big challenge, which has not been very much developed in Argentina but has been successful in many other countries, is the use of cogeneration in association, which leads to a significant increase in technical yields and economic efficiency. Beyond general industrial park guidelines, there are no specific incentives in our country to promote, for instance, heating consortia or shared industrial steam lines. At present, these types of projects are basically a result of private sector decisions.

Finally, we also need to reinforce the concept of geographic efficiency of the power generation grid. Geographic atomization of power generation does not only reduce transmission costs and losses, but also strengthens the grid by decreasing the risk of outages (due to the medium size of power plants), distributes the probability of failures across the territory, reduces the need and operating load of large trunk infrastructure works, and also distributes investment and economic activity expansion opportunities.

4. Current Economic Conditions of the Energy Sector: Towards a Standard Model

In order to conduct an economic evaluation of the conditions faced by a dendroenergy project in Argentina, we took the exercise proposed by the FAO report authors (2020a) as a technical basis, updated it here and improved its formulas. Such exercise consists in a technical and economic modeling of a forest production unit, on the one hand, and of an energy conversion unit, on the other. Both of them can be articulated as separate links or in an integrated manner. A *Eucalyptus grandis* plantation located in the Province of Misiones was selected for the model, due to the outstanding conditions of this province in terms of land suitability and climate, as well as the forest industry installed capacities in the region, including the existence of this activity in the province in the past, the formation of a job market specialized in forest activities, the coexistence of multiple companies and specific providers, etc.

The model proposes that energy will be produced from forest biomass specifically planted for such purpose. This does not mean that, from an operating point of view, forest waste or byproducts from the local market could not be used on a supplementary basis.

The forest production model is an option for alternative land use. As regards methodology, we chose not to record the land value, because we believe it is subject to valuation cycles that could distort the effects we seek to model, and we consider that it could be seen easily later on in our findings. The model transforms the following set of input factors into the product to be obtained, i.e. wood that is already cut and ready to be taken by the next process stage. This process takes place in a time cycle which starts with the forest plantation and includes three harvests (clearfelling and full stumpage), with a 5-year rotation period. After 15 years, the cycle starts again with a new plantation. All the technical coefficients are expressed based on one-hectare requirements and yields within one year.

Input factors (economic expenses):

JO_t	Hiring employees, transformed into amount of wages aligned to a benchmark hierarchical category and market valued
GO_t	Use of fuels and lubricants transformed into equivalent liters of diesel fuel
PL_t	Use of plantation material (seedlings, in the case of *eucalyptus* and pines)
AQ_t	Cost of agrochemicals and other supplies
TR_t	Cost-in-use of specific machinery (including regular maintenance, mainly for tractors and tillage implements, excluding depreciation)
AM_t	Equipment depreciation, including tractor, chainsaws, shed, etc.
IM_t	Specific local taxes (mainly property tax and road maintenance fees), plus other minor overhead costs
AD_t	Administrative expenses, calculated as a fixed percentage ad of subtotal expenses and evenly distributed on an annual basis in the entire cycle

Output factors (economic income):

$P\ R_j$	Valuation of forest harvests (R_j) at the single current price (P)

Economic income and expenses are organized annually, thus obtaining the relevant net cash flow. By valuing all the operations included with a set of prices, we can obtain financial indicators about the kind-of-activity unit, such as net present value (NPV) and internal rate of return (IRR).

Our methodology consists in taking the minimum price of 1 $\text{Mg}_{\text{dry basis}}$ of wood produced as a choice variable that offsets the costs incurred, setting the NPV of the entire cycle equal to zero, for a given discount rate. Given the extension of the production process over time, the relevance of the financial analysis is essential, so the notion of cost in this case is basically understood from a financial point of view. Thus, we come to the concept of a minimum price that balances the financial flow as a cost. This exercise is solved by iterative approximation methods, as is the IRR calculation.

The first step is to calculate the NPV, including the initial year (t=0) as the investment required for the first plantation:

$$NPV = \sum_{t=0}^{T} \frac{1}{(1+i)^t} (II_t - EE_t)$$

Where:

t represents the successive project years, up to *T*=15 in our case,

II_t represents income for the year *t,*

EE_t represents expenses for the year *t,*

i is the discount rate selected for the simulation.

Then, we break down as follows:

$$II_t = \begin{cases} \boldsymbol{P}\, R_j, & t = 5, j = 1\,; \quad t = 10, j = 2\,; \quad t = 15, j = 3 \\ 0, & t \neq \{5; 10; 15\} \end{cases}$$

$$ST_t = JO_t + GO_t + PL_t + AQ_t + TR_t + AM_t + IM_t$$

$$AD = \frac{ad}{T+1} \sum_{t=0}^{T} ST_t$$

$$EE_t = ST_t + AD$$

where we can see the income and expenses variables, as described above, and where subtotal ST_t is an intermediate function that allows us to estimate the administrative costs as a fixed proportion of the gross sum of all subtotals in the entire cycle, and it is later allocated in equal shares on an annual basis.

The exercise is solved by computationally calculating the value of $\boldsymbol{P}$, so that the following equality may be obtained, integrating the previously developed terms:

$$\sum_{t=0}^{4} \frac{-1}{(1+i)^t} (JO_t + GO_t + PL_t + AQ_t + TR_t + AM_t + IM_t + AD) +$$

$$+ \frac{\boldsymbol{P}\, R_1}{(1+i)^5} - \frac{1}{(1+i)^5} (JO_5 + GO_5 + PL_5 + AQ_5 + TR_5 + AM_5 + IM_5 + AD) + \cdots = 0$$

Every resolution of this model is a simulation exercise, which may have several variations of interest. In this case, we proceeded with simulations of the relative price set for the years 2010-2020, using two reference discount rates (5% and 15%). We also carried out a sensitivity analysis in view of selected variables, as shown below. In all cases, prices are fixed for the year of analysis throughout the simulated cash flow, as if it were an *ex ante* economic assessment of an investment project repeating annually.

The sources of information and the data construction are shown below:

$JO_t = x_t^{jo} p_{jo}$	x_t^{jo}: labor input in year *t* as the amount of equivalent wages (aligned to a benchmark hierarchical category)
	p_{jo} = [USD/\$] ${}^{1}/_{TC}$ × [\$] equivalent wage. The equivalent wage is obtained by calculating the category “sueldo mensual peón general sin comida y sin SAC” (minimum rural monthly wage) × ${}^{1}/_{12}$, according to official resolutions from the Comisión Nacional de Trabajo Agrario (National Agricultural Labor Commission)
$GO_t = x_t^{go} p_{go}$	x_t^{go}: fuel and lubricant input in year *t*, expressed in equivalent liters of diesel fuel
	p_{go} = [USD/\$] ${}^{1}/_{TC}$ × [\$] Diesel fuel price, average in July each year in a selected gas station, Res. Sec. Energía n° 1104/2004
$PL_t = x_t^{pl} p_{pl}$	x_t^{pl}: plantation material (seedlings, in the case of *eucalyptus* and pines) input in year *t*
	p_{pl} = [USD/\$] ${}^{1}/_{TC}$ × [\$] plantation material price in the base year, updated using IPIM (Wholesale Price Index)
AQ_t	[USD] expenditure in agrochemicals and other supplies in year *t*, valued in USD in the base year
$TR_t = x_t^{tr} p_{tr}$	x_t^{tr}: specific machinery use, expressed in hours of work
	p_{tr} = [USD] Cost-in-use of specific machinery, valued in USD in the base year
AM_t	[USD] Full equipment annual depreciation, which remains constant for the whole cycle, valued in USD in the base year
IM_t	[USD/\$] ${}^{1}/_{TC}$ × [\$] Specific local taxes plus other minor overhead costs, valued in the base year
R_j	[Mg$_{\text{dry base}}$] forest harvest; $j \in \{1; 2; 3\}$; estimated yealds taken from previous studies and trials, which remain constant for all simulation cycles
P	[USD/Mg$_{\text{dry base}}$] dry base forest biomass price
TC	Nominal Exchange Rate (BCRA, Comunicación "A" 3500)

As we can deduce from the detailed construction of data, all values are converted into current U.S. Dollars (USD), so that the model can be watched closely over time, in a context of significant exchange rate variations. The base year for the calculations was 2017. Items with a market price approximately tied or tending to follow the foreign exchange rate, as well as the tax component, were converted into dollars as of the base year. Fuels and lubricants were converted into equivalent liters of diesel fuel in the base year, and follow such price variations. Input valued in pesos, which is basically limited to plantation material, is adjusted according to the internal wholesale price index (IPIM, for its acronym in Spanish, general level) based on an average for July each year. Employee hiring was quantified in equivalent wages in the base year, and adjusted according to the official variation for such category defined in the relevant resolution by the National Commission on Agricultural Labor (CNTA) of the Ministry of Labor issued annually by midyear. Currency conversions are made at the nominal wholesale exchange rate (Central Bank of the Argentine Republic [BCRA], 3500 "A" Communication) based on an average for July each year.

For 2020, the model provides a simulation resulting in a minimum price of USD 32.15 per Mg_{db} for a 5% discount rate and USD 41.88 per Mg_{db} for a 15% discount rate. This range shows the quantitative influence of financial conditions in this kind of project. The tables below show the composition of costs classified in model items, calculating the applicable present value of the entire cycle flow for both benchmark rates, respectively:

Cost composition @ 5%	
Item	%
Wages	37.17
Fuel and lubricants	19.37
Equipamient depreciation	15.04
Equipamient cost-in-use	11.72
Specific taxes and overheads	5.01
Plantation material	4.83
Administration	4.74
Other	2.11
Total	100.00

Table 4: Minimum simulated price cost composition @ 5%

Cost composition @ 15%	
Item	%
Wages	39.13
Fuel and lubricants	16.60
Equipamient depreciation	14.59
Equipamient cost-in-use	9.50
Plantation material	7.79
Specific taxes and overheads	4.86
Administration	4.60
Other	2.93
Total	100.00

Table 5: Minimum simulated price cost composition @15%

A comparison between Tables 4 and 5 shows how the entire process becomes more expensive at higher discount rates, in addition to seeing a certain change in cost structure, since, according to the temporary profile of expenses, weightings in the present value calculation are modified.

However, some characteristics are highly stable, such as the marked prevalence of the labor item as a major component (this repeats invariably in all simulations below) and the importance of fuels and capital goods depreciation, followed by all the other components.

Regarding the model sensitivity analysis, we find that, based on the 2020 simulation and with a 5% discount rate (as an example), a 10% increase in the wage value raises the minimum price by 3.9%; a hike of 10% in the pump price for diesel fuel causes the minimum price to increase by 2%; and a nominal 10% depreciation of the peso leads to a 5.9% reduction of the minimum price. All these are total direct relationships *cæteris paribus* and in the context of the present values of variables. For partial or combined effect testing, it is advisable to update the entire set of prices feeding the model, or to simulate them by developing complete scenarios, which requires a macroeconomic model supporting those relationships and implied baseline scenarios.

In our case, we updated the model input data for all the years in a series. The results we obtained are summarized in Table 6 below, including a few reference variables, such as nominal exchange rate, equivalent wage, wholesale price index, and the benchmark price of diesel fuel, so that relative prices may be compared over time. The values in the table are the ones expected each year by midyear.

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Exchange Rate ($/USD)	3.93	4.13	4.55	5.44	8.16	9.04	14.14	17.17	27.62	43.79	69,54
Wages ($)	184	230	276	340	463	600	768	1,054	1,272	1,958	2,781
Domestic price level - IPIM (/dic15)	46	52	58	66	85	96	130	148	218	335	484
Diesel fuel ($/l)	3.23	3.63	5.27	7.07	10.80	11.53	16.23	18.10	25.54	42.59	52.09
Pmin (USD/Mg) @5%	36.01	39.55	43.60	45.27	43.23	45.91	40.67	41.94	35.81	35.75	32.15
Pmin (USD/Mg) @15%	47.80	52.67	57.68	59.57	56.43	60.24	53.09	54.94	46.69	46.46	41.88
Pmin ($/Mg) @15%	188	217	263	324	460	545	751	943	1,290	2,034	2,912

Table 6: Forest biomass minimum prices and other selected prices.

To interpret these results correctly, we should consider, among other aspects, that the model is outlined as an investment option based on cost of land that has already been covered (it is not included in these values), and that the price obtained is a minimum that balances the cash flow present value at the given discount rate. Consequently, there is no profit once the financial opportunity cost is compensated. This means that, under such technical conditions, real expected market prices would necessarily be higher for the activity to be deemed feasible.

After modeling the forest biomass production, we completed the proposed analysis with the inclusion of energy conversion in a thermal power plant that will consume the forest biomass produced, particularly following up on the technical-economic model developed by C. Zaderenko in FAO (2020a) and Zaderenko (2012). We directly took the most competitive variant of the model, i.e. a power plant with a delivery capacity of 2 MW in cogeneration (electrical-thermal power), providing the most efficient use of biomass of those discussed in the above mentioned work.

Similarly to what was done with the primary production stage, in this case income and expenses variables were also converted into current U.S. dollar values (USD), using the same adjustment criteria based on variations in wages, internal prices and direct dollarization, according to the type of operating cost. Income results from the energy sold to the grid (SADI), and these sales are made under U.S. dollar denominated agreements. Like in our previous exercise, the price of biomass to be consumed was set as a selection variable. Therefore, in this case, the successive simulations under the price conditions for each year, result in maximum prices that the industry can pay for wood, given the fixed sale price of the electrical power to be delivered and deducting the price for cogenerated thermal energy from the costs.

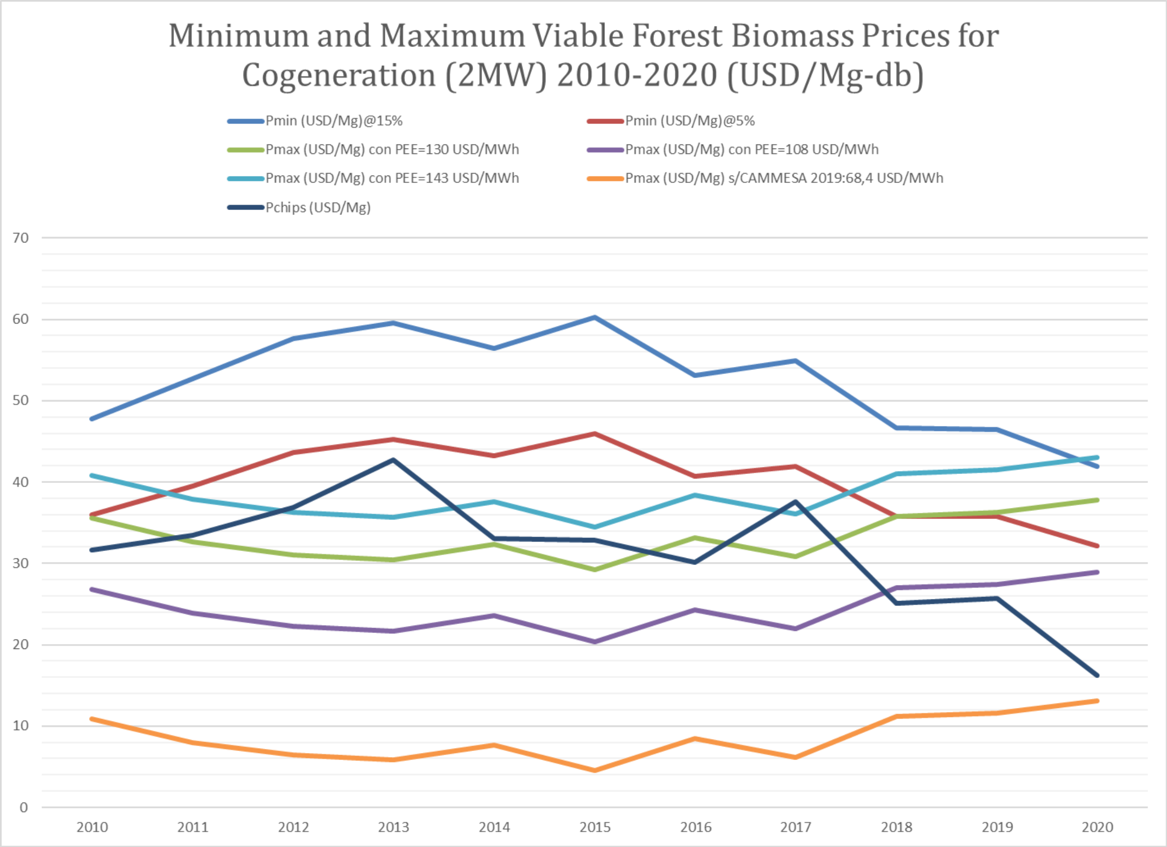
The results we obtained are shown in Table 7 below. For reference purposes, this table also includes forest production model minimum prices at 15% and 5% rates and the market price for each year in the series for *eucalyptus* chips with bark (annual average in the Mesopotamia Region, INTA Agricultural Research Station at Concordia), as alternative fuel. In the latter case, the price was converted into equivalent $Mg_{\text{dry basis}}$ and expressed in U.S. dollars using the same exchange rate series included above. Even though in Misiones pine chips are currently more frequent, we take this specific series of data as a reference due to continuous availability and methodological stability.

Four maximum prices are represented for energy conversion feasibility, which are associated with the model solution for minimum, maximum and medium prices in effective renewable energy (RENOVAR Program) bids (USD 108, 143 and 130 per MWh), in addition to the solution derived from charging a reference marginal wholesale energy price for the system as a whole (CAMMESA), which was 68.4 USD/MWh until the end of 2019.
Even though the awarded projects under the RENOVAR Program were not active before 2017, the reference is equally useful in comparative terms.

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Pmin (USD/Mg) @15%	47.80	52.67	57.68	59.57	56.43	60.24	53.09	54.94	46.69	46.46	41.88
Pmin (USD/Mg) @5%	36.01	39.55	43.60	45.27	43.23	45.91	40.67	41.94	35.81	35.75	32.15
Pchips (USD/Mg)	31.64	33.43	36.90	42.73	33.09	32.85	30.13	37.57	25.09	25.69	16.18
Pmax (USD/Mg) with PEE=108 USD/MWh	26.76	23.84	22.25	21.65	23.55	20.41	24.32	22.02	27.00	27.44	28.97

Pmax (USD/Mg) with PEE=130 USD/MWh	35.56	32.64	31.05	30.45	32.35	29.21	33.12	30.82	35.80	36.24	37.77
Pmax (USD/Mg) with PEE=143 USD/MWh	40.80	37.89	36.29	35.70	37.59	34.45	38.36	36.06	41.04	41.48	43.01
Pmax (USD/Mg) with PEE=68 USD/MWh	10.91	8.00	6.41	5.81	7.71	4.56	8.48	6.18	11.16	11.60	13.13

Table 7: Minimum and Maximum Forest Biomass Prices for Cogeneration.



Graph 1: Minimum and Maximum Viable Forest Biomass Prices for Cogeneration.

As we can see by analyzing Table 7 and the Graph 1, the model is not feasible for most of the years in the series and in the average conditions of the various scenarios of possible assumptions. The minimum price resulting from biomass production and supply conditions is higher than the maximum price that the transformation stage may compensate, always under the already specified feasibility conditions. This worsens the diagnosis if we hypothesize about private investment initiatives intended to run risks. Generally, the option to produce energy from chips, as an example of forest and forest industry byproduct, is always potentially more feasible and profitable according to this analysis.

With chips being merely an example, this premise can be generalized for sawdust, bark and other production byproducts or waste. In a specific real and more complex case of energy production from forest byproducts, such scheme should probably need to be supplemented with some degree of coverage with dedicated plantations to help mitigate biomass supply impacts and reduce both technical and market risks. Furthermore, we should consider that setting up a power plant to be mainly supplied with byproducts implies either long-term agreements with suppliers that have a certain degree of securitization, or that it should be directly integrated into the industry, at least for most of the material flow, so that shortage risks are reasonably managed.

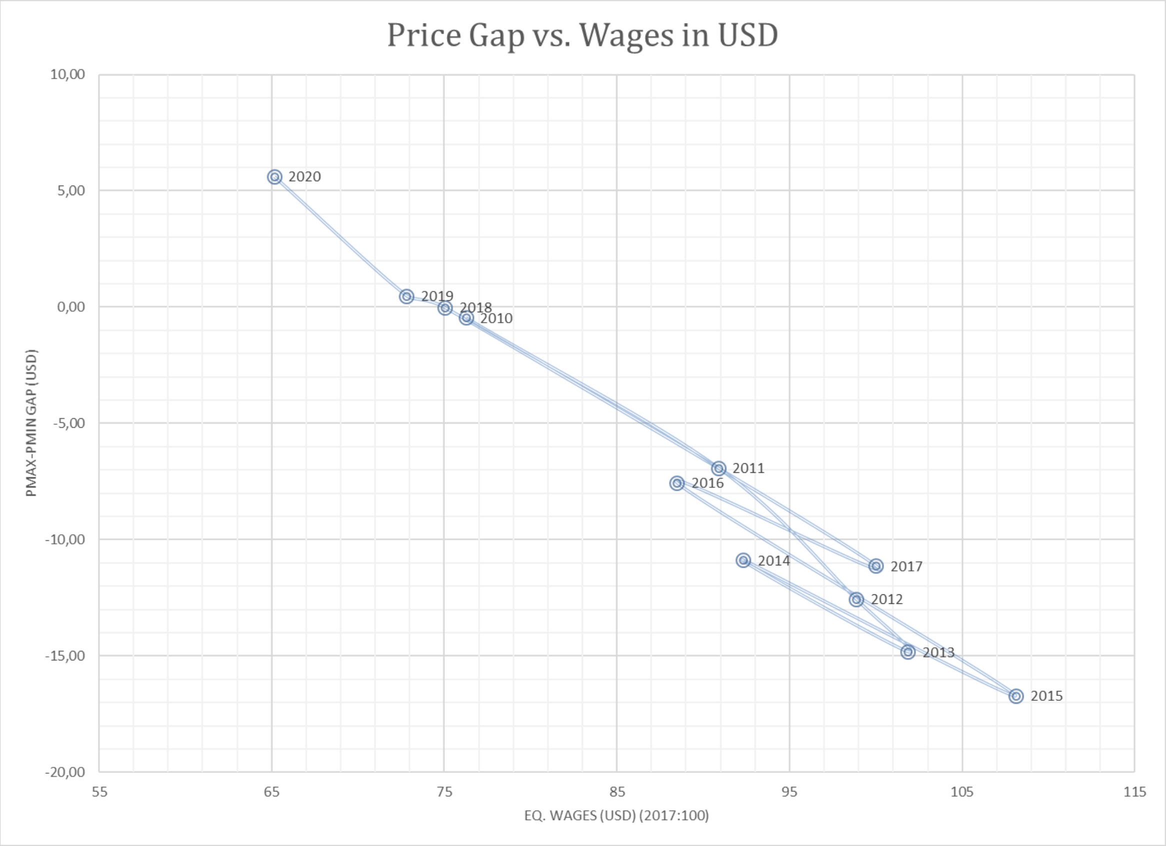
It should be noted that the three resulting prices for electrical power under the RENOVAR Program include a government subsidy, compared with the energy market price in our country. The subsidy in the lowest price accounts for over 50%. However, as we show in the first section of this paper, such subsidy is often justified by the already mentioned externalities that are taken into account for this type of energy production, and due to its strategic nature. In the first case, the effect is direct. In the second, the incentive is aimed at the development and improvement of the conditions under which it occurs, so that economic efficiency in the sector may increase in the future by means of technological and production scheme maturity.

It is not until 2018, under highly pressing conditions, that the hypothetical project would be somewhat feasible at the highest subsidy price and a 5% discount rate. But this would not seem to be a sufficient incentive for investment under such a level of volatility and within an adverse time frame. By 2020, the conditions continue to improve and, at this point, a plausible feasibility scenario can be observed with greater likelihood.

This observation leads us to the research question: What characteristic of this set of changing relative prices is most directly related to project feasibility? After analyzing the changes in economic conditions carefully year by year, and their respective results, and taking into account model sensitivities, we focused our attention on the relationship between the calculated price caps and the evolution of wages and the exchange rate. In order to limit our observation to the main focus of interest, we created the variable “gap” between maximum and minimum prices, which is the simple difference between a selected maximum price and a selected minimum price. The decision about which one to take in each group does not have a significant impact on the results, because the main interest lies on the variations, not on the level.

After a series of alternative hypothesis tests, it was found that the strongest relationship occurs between the price gap and the dollar-denominated wage evolution index, as we can see in the graph below. This linear relationship which had a negative sign throughout a decade, including all the macroeconomic changes therein, as well as the changes of political cycle during such period, suggests that the feasibility of dendroenergy projects in Argentina is directly associated with general macroeconomic competitiveness at the national level.

Even though any interpretation of these observations implies in some way an underlying macroeconomic model, and although it is not a central purpose of this paper, we can conduct a test —like a hypothesis to develop in future in-depth analyses— to see that when nominal peso depreciations involved a steady pass-through to domestic prices, in contexts of economic growth and readjustment of formal employee wages, salaries expressed in dollars from this series reached their highest levels and project feasibility conditions were the worst. Meanwhile, when nominal devaluations occurred in a more recessive context, wages and internal costs expressed in dollars were lower and this had a positive impact on the target price gap. Thus, in a dynamic context of exchange rates that remain competitive without an (excessive) pass-through to domestic costs, the price gap would come closer to project feasibility, whereas in the opposite case, the gap would change towards worse conditions for this type of projects.



Graph 2: Price Gap vs. Wages in USD.

Improved feasibility conditions can be seen towards the last three years in the series, concurrently with a context of devaluation and recession. This produces, among other aspects, a steady real devaluation and reflects, for instance, in a growing trade balance, which changed its sign during that period. The question that an observer of these relationships may ask is: Will the feasibility condition reached be sustainable?

As a way to draw some kind of parallelism, even though the studies are different and their approaches are not very much related, Navajas (2015) builds a clear example model integrating core macroeconomic aspects with (general) energy policy. Among other interesting aspects, Navajas points out the great difficulty —at least from the point of view of actual policy implementation possibility— in preventing a devaluation from causing a hike (even greater than the devaluation proportion) in energy prices in order to balance supply profits. Extending the analysis to reach final energy demand, Hancevic *et al*. (2016) show that, as a result of the serious problems caused by this structural restriction, the economic burden of the imbalance between supply costs and final demand prices in certain political cycles may be transferred to government budget administration, pushing the unavoidable tariff adjustment out to the future, thus accumulating social debt and also necessarily delaying investment in the sector. These readings point out characteristics that are somehow common to the restrictions found in our exercise and the general problems of the energy sector, regardless of whether the energy sources are renewable or not.

In sum, the analysis proposed in this section shows that the economic conditions that determine the development of the dendroenergy production potential in Argentina are associated with the difficulties to keep a competitive relative price scheme over time, regardless of the margin for technological improvement and efficiency in general. These problems make this activity join the general case of agro-industrial activities (and the forest industry in particular), with a still latent significant potential for development.

5. Final Comments

In this paper, we sought to address the potential, the problems and the perspective of dendroenergy in Argentina, based on the progress made thanks to the INTA-FAO-Probiomasa consultancy project, updating and incorporating elements in addition to those already available to date, and emphasizing the incentives for dendroenergy development. Our discussion went from the quantification of the primary production potential to a closer look at a few specific actual cases of energy production. Then, we took a deeper look into the rationale of current regulatory incentives. And finally, we conducted an economic modeling exercise to serve as a benchmark or reference case for the activity.

A first thoughtful comment that we can add to the work exposed so far is that some of the incentive tools discussed in this paper have gradually come to fruition in the past few years, as we can see in the RenovAR Program, with the marked growth of the renewable energy sources share in the final demand coverage. A few days before this paper was completed, on September 13, 2020, the share of renewable energy sources hit a record high, peaking to 22.6% of the total (CAMMESA), under a combination of particular weather conditions. At present, biomass energy supply is steady at around 8%.

In contrast, we can also see that at least some of the projects awarded under such program, particularly those related to forest biomass, are on hold until business conditions look better. Evidently, the current economic situation is complex, but we will not go into further details here, since it goes beyond our scope and purpose. However, we do consider it advisable to note that, in the local experiences described from the perspective of key players in FAO (2020c), company representatives express skepticism and insecurity in connection with the country's regulations and macroeconomic instability. As for the second appreciation, our modeling exercises in Section 4 support such doubts to a certain extent, although, in any case, companies might also have conducted the analysis raising the same doubts when they signed up for the Program. With respect to the regulatory criterion, it is striking that precisely those instruments that seek to encourage investment with a set of special rules are perceived in a negative way.

The regulatory framework to promote this sector precisely forms a block which is intended to somehow safeguard a number of special preferred conditions which are essentially separated from the general path followed by the rest of the economic policy. A unilateral reception of the private sector viewpoint could mean that the incentives are not enough, or that the guarantees offered are vulnerable. However, if we step back further away, it has become increasingly difficult to justify greater subsidy levels for the activity, due to the difference observed in economic efficiency regarding other types of renewable energy. The most serious exception we could make in this case would eventually be the strategic criterion: a development policy to actively promote increased efficiency, whether in economic, environmental or social terms, from a wider perspective.

From another point of view, another dimension that adds to the analysis is the issue derived from the relationship between the energy sector and the external sector of the economy. Evidently, this problem is not new or original, and it is not even specific to this type of energy generation. In this case, however, part of the frequent criticism to this way of encouraging the use of biomass energy is the great level of dependence on imported technology and equipment, which is in opposition to the promotion of locally centered technological development (e.g. Manrique, 2020). This problem does not only entail consequences on the foreign currency flow, but also on the effects on the local production and employment profile. Attention to this type of observations and the subsequent implementation of corrective proposals should not be incompatible with the steps taken to boost the sector.

Finally, from a more global perspective and maybe over a longer time horizon, our proposal is to avoid overlooking the fact that, while advancing towards the production of dendroenergy and other types of bioenergy, it is strategically advisable to further a better use of materials and their respective specific potential. This is somehow modern, but it is no longer new, and Argentina has important scientific and technological capabilities in this respect.

With specific exceptions, the use of materials for energetic purposes implies always building on residual value, and any alternative use is often valued on a priority basis. This explains the importance of not losing focus on forestry in order to solve a unilateral energy problem, and of seeking general efficiency by using the materials that can be produced, especially in Argentina, in industries that range from solid wood uses to different types of biorefineries or bioreactors. There will always be waste and byproducts from all the processes, and they may be used for energy purposes. In fact, this is already occurring in emblematic cases such as the multiple-use pellet market in the Province of Misiones. The development of these potentials can also be identified with that of the so called circular economy and with the strengthening of bioeconomy.

Along with the previous observation, we also include the importance of geographic distribution for dendroenergy projects in this group of ideas that seek to add value to dendroenergy production. Distributed generation, including regulatory and tariff instruments, is part of the necessary incentives, but a debate can be added about the role of the State in a more profound planning of the country's future energetic and bioeconomic system. All efforts to atomize energy supply and distribution, provided this is done at least with no efficiency loss, will result in a more robust and more cost-effective system, leading to a more balanced territorial development.

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