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The potential for sustainable biomass pellets in Mexico: An analysis of energy potential, logistic costs and market demand

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ABSTRACT

Pellets have received increasing international attention lately because of their potential as clean, affordable and renewable energy sources, particularly when produced from agricultural and forest residues. However, knowledge about feedstock availability, costs, and potential users of biomass pellets is scarce in Mexico. In this paper we examine the potential for biomass pellets to become a sizable low-carbon, renewable energy source that could compete with and substitute fossil fuels in specific economic sectors in Mexico. We estimate that the market energy potential for pellets from currently available agricultural and forest residues in Mexico is between 131 and 233 PJ/yr, with total costs ranging from 6.3 to 12.8 USD/GJ. Sawdust pellets have the lowest cost and could compete with chips and sawdust for supply distances greater than 400 km and 480 km, depending on the production cost. At current fossil fuel prices, sawdust pellets could compete with LPG, fuel oil and residential natural gas. Potentially, pellets could completely replace natural gas demand and 73% of LPG demand for residential and commercial heating. To compete with coal and petroleum coke used in the industrial and power sectors, pellets would need an incentive of 30 and 50 USD per non-emitted tCO_2 over and above their selling price. Pellets may potentially mitigate up to 18% of GHG emissions from electricity production in Mexico.

1. Introduction

Currently, there is a growing interest in substituting fossil fuels (abbreviated throughout this paper as FF) by renewable energy sources. Solid biofuels for heat and electricity production show high CO_2 emissions mitigation potential in the short and medium term [1]. According to IEA [2], pellets are among the most common processed solid biofuels used worldwide, mainly for household heating in small biomass boilers, while in the industrial sector they are predominantly used in combined heat and power systems (CHP) and district heating [3]. In electricity production, there has been an increase in the consumption of pellets by power plants, as is the case in Asia [4,5] and Europe [6], where pellets are mainly used for co-firing with coal [3,7,8].

Internationally, wood pellets are the most commonly produced and commercialized solid biofuels [7,9,10], with sawdust as the main raw material [11]. In 2014, the global consumption of pellets surpassed 25 million tones [4,12], with U.S.A., Canada and Russia being the largest exporters to the European market [6], which is the main consumer worldwide. Also a potential market for agricultural-waste pellets is believed to exist [13,14], mainly using straw, husk and miscanthus as raw materials [15].

In Latin America, very few countries possess a mature industry for the production and use of pellets. In Brazil, although the internal consumption is low, exports to Europe have grown in recent years, reaching 0.08 PJ in 2014 [16]. Moreover, Brazil has the potential to produce 465 PJ from agriculture residues, mainly from the harvest of

Abbreviations: C, commercial; CECs, clean energy certificates; CHP, combined heat and power; DM, dry matter; FF, fossil fuels; FT, pruning from fruit trees; GHG, greenhouse gases; GJ, Giga Joule; h, hour; HR, harvest residues; I, industrial; KWh, kilowatt hour; LHV, lower heating value; LPG, Liquefied Petroleum Gas; M, million; MP, market energy potential of pellets from resources of immediate availability; Mt, mega tons; $MtCO_{2eq}$, million metric tons of carbon dioxide equivalent; MXN, Mexican pesos; NPV, net present value; PJ, petajoule; R, residential; SBF, solid biofuels; t, tonne; TP, technical energy potential; USD, United States dollar; yr, year; ¢, cent

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sugar cane, and 1400 PJ from the forest industry, both of which materials could be employed in the production of pellets [3]. Argentina produces about 1 PJ of pellets using residues from the forest industry [3] for internal use, household heating or substitution of FF in the industrial sector.[1] In Chile most of the pellets produced are used for household heating and their use in the electric power sector through cofiring is on the rise [17].

Meanwhile, Mexico is highly dependent on fossil fuels to meet its energy needs. In 2014, FF contributed 87.9% of primary energy use, with petroleum and natural gas at 63.4% and 23.5%, respectively [18]. Owing to this dependence and the environmental impact of the emission of greenhouse gases (GHG), there is interest in increasing the share of renewable energies in the national energy mix. For example, the Law of Energy Transition [19] establishes that by 2024, clean energies should fulfill at least 35% of all power sector needs.

Mexico's solid biofuel (SBF) potential is estimated to be 2500 PJ/yr [20], potentially 28% of primary energy demand. Primary and secondary forest and agricultural residues have the largest energy potential [21] and estimates suggest that this will increase in the coming years [22]. So far in Mexico there is no large-scale usage or production of pellets and there are no detailed studies about their technical energy potential, their logistic costs or their specific uses. Logistic costs are very important to estimate the final cost of biomass fuels, which, being voluminous and low-density [23], have high transport costs [24–26] and cannot be efficiently transported for long distances [27].

The use of agricultural residues in their original state as fuels is mainly limited by these logistical challenges [28], since their production tends to be geographically dispersed [29], and seasonal [30–32], and because their energy content per ton is much lower than e.g. in FFs [33,34]. The main advantage of pelletization of these residues is in the reduction of logistical costs. It also allows them to be stored all year round and helps to ensure that a continuous supply of fuel is available. Pelletization could moreover provide an important opportunity for valorization of the currently unused residues in the forest industry in Mexico. It could also help to resolve several problems identified in the National Forest Program 2014–2018 [35], by reducing forest fires and pests, promoting the construction of forest roads and increasing the competitiveness of the industry.

Few studies in Mexico have analyzed the use of solid biomass fuels and very few have considered the use of pellets. IRENA [36] and Rios and Kaltschmitt [22] studied the geographical distribution of the biomass fuel potential in Mexico, but logistic costs were not evaluated. Valdez-Vazquez [37] examined the spatial distribution and potential of the country's agriculture residues for conversion into bioenergy through combustion and fermentation, but did not evaluate the potential for or costs of pellet production. These authors also recommended the evaluation of the potential of solid biofuel by-products from the processing of fruits for juices. García et al., Aldana et al. and Rembio [38–40] calculated the sustainable potential of biomass and its impact in the substitution of FFs. Although García et al. [21] assessed the technical potential of pellet production, they did not consider the logistic costs.

This paper is more comprehensive in that it adds to previous studies the examination of a wider range of biomass resources including residues from citruses and fruit tree prunings that have never been considered in Mexico. Importantly it calculates logistic costs associated with pellet management and transportation to potential users and compares this with SBFs over different transportation distances. Furthermore, the study examines the extent to which FFs could be substituted by pellets and the resulting mitigation potential in the main sectors of the economy (industry, residential, etc.). Within each sector, potential pellet users are also evaluated on the basis of the technical characteristics of their demand and current FF prices. The results of this study will be useful for better understanding the current possibilities for the large-scale use of pellets in Mexico.

The goals of this study are:

(1) To determine the energy potential for pellet production from agriculture and forest residues in Mexico
(2) To estimate the production and logistic costs of pellets, taking into account their final uses
(3) To compare the estimated costs of pellets at their point of delivery with the costs of other solid biofuels for different transportation distances
(4) To identify potential pellet users within the different sectors of the Mexican economy based on technical and economic criteria
(5) To make a preliminary examination of policy options to foster the large-scale use of pellets in Mexico

2. Methods

The methodology comprises three main aspects: a) estimating the energy potential for pellet production; b) the estimation of pellet production and logistic costs, where we also examine economic viability depending on transportation costs, and c) the identification of potential users in different sectors, considering technical and economic criteria.

2.1. Energy potential of pellets

In the first place, technical energy potential (TP) was estimated. TP is defined here as that proportion of the theoretical biomass potential from forests and agriculture residues that in reality can be obtained, taking into account the limitations of biomass production practices and other uses and ecological restrictions [41,42]. TP was calculated according to Eqs. (1), (2) and (3).

$$TP = PA + PF \tag{1}$$

$$PA = PPR + PSR \tag{2}$$

$$PF = PFM + RFI \tag{3}$$

Where PA is the technical energy potential from agriculture residues; PF the technical energy potential from current forest resources and residues in the country; PPR and PSR the energy potential for primary and secondary agricultural residues respectively [22]; PFM is the energy potential from native forest management and logging residues[2]; and RFI is the potential from residues from industrial forestry, which mainly consist of sawdust and slabs (unusable sawnwood).

- *Agricultural technical potential (PA)*
  Agricultural residues include those from five crops (sugar cane, corn, sorghum, citrus and wheat). These make up more than 90% of the agriculture energy potential according to Valdez-Vazquez et al. [37]. Technical energy potential from primary (PPR) and secondary (PSR) agriculture residues was estimated using the following expression adapted from [22,37,43].

$$PPR = PP \text{ x } PRGI \text{ x } Av_p \tag{4}$$

$$PSR = PP \text{ x } SRGI \text{ x } Av_s \tag{5}$$

Where PP is the annual crop production, PRGI and SRGI are the primary and secondary residue generation index for each crop individually, and Av_p and Av_s the availability of the primary and secondary residues to be used as energy carriers. Av_p considers two factors: the residue removal rate and the competition with non-energy uses. The first factor is used to account for the residues that are

[1] 1 tMS wood equals 20 GJ. 1 tMS agriculture residue equals 15 tMS.

[2] PFM is estimated as native forests woody biomass growth discounting the biomass resources that are used for non-energy purposes (i.e., timber, wood for pulp and paper production, etc).