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Research Article

Biomass Feedstock Availability for the Supply of Bioenergy in the Lerma Valley (Salta, Argentina): an Evaluation for Territorial Energy Planning

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Abstract

Argentina plans to reach from 3% to 10% biomass participation for the internal supply of primary energy for 2015. However, biomass exploitation requires detailed studies at a local level for territorial energy planning, to achieve the expected energy and environmental benefits. This study, performed in the north of Argentina (Lerma Valley, province of Salta) is a step in this direction. The objective was to identify, characterize and quantify biomass feedstock availability in the region and its energy supply, studying the demand and utilization alternatives; and building different methodologies of quantification. The feedstock examined includes agricultural waste (AWB), municipal solid waste (MSW), and woody biomass (three main ecosystems and four species of *Acacias spp.*). They are annually producing 17,800 $t.yr^{-1}$ (equivalent to 206,000 $GJ.yr^{-1}$) of AWB; 24,100 $t.yr^{-1}$ (around 34,000 $GJ.yr^{-1}$ as biogas) of MSW (wet weight) and 213,000 $t.yr^{-1}$ (or 3.1 million of $GJ.yr^{-1}$) of woody biomass. The Acacias constitute 74% of the Shrubland's potential bioenergy (213,000 $GJ.yr^{-1}$). This report will make possible the application of realistic energy projects for the area, promoting efficient exploitation of resources and generating positive local impact. The main bottlenecks for the implementation of such projects and some possible strategic solutions are identified. The proposed methodologies might be used to other geographical regions, within programs of territorial energy planning. In addition, the new data set of available worldwide biomass resources and the scientific knowledge in the field of bioenergy that has been generated, both constitute fundamental contributions for bioenergy promotion.

Keywords: Bioenergy; Biomass Feedstock; Territorial Planning; Native Forests; Organic Waste

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1. Introduction

Renewable Energy Sources (RES), which participate in the global power grip on an average of 11%[1] (IEA, 2012), are being promoted as an alternative to non-renewable sources that have limited reserves (BP, 2012) and, although they are subsidized in many countries (COM, 2011), they show great price movement which threatens energy security (IRENA, 2013; Becker and Fischer, 2013). The EU, for instance, has set the goal to achieve 20% of RES participation in gross final energy consumption and 10% RES participation in transportation for the year 2020. In general terms, promotion policies of RES, or some kind of participation objective, exist at the national level in at least 118 countries, of which more than half are developing. This indicates that the number of countries with specific objectives in RES has doubled in the last 6 years (REN 21, 2012). The countries that support RES growth also aim at utilizing the benefits of these renewable and less contaminating resources, in pursuit of achieving national and international environmental aims, mainly regarding the reduction of Greenhouse Gas emissions (GHG) and other local pollutants (Akbulut, 2012; Li et al., 2013; Zhang et al., 2013; Felten et al., 2013; Sardianou and Genoudi, 2013).

Biomass (which includes organic resources not fossilized in different states of transformation) involves close to 80% of RES consumption (IRENA, 2013). In relative terms, almost 25% of bioenergy is exploited in industrialized countries and the other 75% is utilized in developing countries (Parikka, 2004), where it is anticipated that the biomass will remain as an important global energy source in the next century (Eubia, 2013). Within this category, traditional and modern uses of biomass can be distinguished. The first group is identified mainly – not exclusively – as the biomass obtained without a commercial transaction. It is mainly fuelwood utilized for cooking and heating (but also agricultural, livestock, and forest waste) and it involves more than 80% of the current use of biomass (IEA, 2012). Modern biomass is characterized by being commercialized in the market and is utilized for electrical energy generation, industrial and domestic heating, as well as biofuel production for transportation (Karekezi et al., 2004; Smeets et al., 2007; IEA, 2008; Demirbas, 2009; Rajvanshi and Sharma, 2012; REN 21, 2012).

In Argentina, the biomass, considering fuelwood (0.8%), bagasse[2] (1.2%) and an uncertain participation of "other primaries" (agricultural waste, quebracho sawdust, black liqueur[3] and non-distinguished solar and wind energies) reaches 3.5% participation in the national power grip -of 76,000 ktep in 2010- (SEN, 2010). These figures leave traditional uses of biomass out of every register in the provinces (SEN, 2010; Grassi, 2012). Bioenergy could meet 10% of the internal supply of primary energy up to 2015 (SEN, 2013), as it is the ambition of the national project Probiomasa (Promotion the use of Biomass for Bioenergy), which aims at incorporating the generation of 200 MW of electricity and 200 MW of thermal power. This could mean, with the replacement of fossil sources, the reduction of 9.5 million tons of $CO_{2eq.}yr^{-1}$ in agricultural, livestock and energy sectors (SEN, 2013). The project assumes that biomass utilization is neutral in carbon emissions insofar as generated emissions had previously been fixed in vegetal tissues (Thornley and Cannell, 2000; Kraxner et al., 2003; Kirschbaum, 2003; Scarlat et al., 2013). This project will add efforts to the national objectives for the generation of 8% of electricity from RES for 2016

[1] Other information sources point out that the RES participation currently reaches 17% (REN 21, 2012).
[2] Bagasse is the dry pulpy residue left after the extraction of juice from sugarcane, used as fuel for electric generators, for example.
[3] Waste generated in the woodchip chemical cooking process to obtain chemical pulp.

(Law 26,190). Its first step was executed through the GENREN Program (Generation of Renewables) which invited tenders for 1000 MW of electrical generation of RES in 2009, with 12% corresponding to thermal generation with biofuels (three blending terminals of 34 MW and one of 8.4 MW, that in 2012 had not yet been built for lack of financing) (James, 2012). Projects of other organic resources to energy have not been tendered in this program[4] (James, 2012; Bondolich, 2012; Fuchs, 2012). In Argentina there are more than 80 bioenergy projects in different stages: operation (286 MW of installed capacity), construction (219 MW) and portfolio (around 86 MW thermal and electrical generation) (Grassi, 2012). Particulary, the energy crops for biofuels (biodiesel) boosted by national government and by international markets, have created great controversies, mainly for the land use changes and associated impacts (Salomon et al., 2006; Seijo, 2008; Van Dam et al., 2009; Panichelli et al., 2009; Semino et al., 2009; Rodríguez and Jacobo, 2010; Tomei and Upham, 2009; Gnansounou, 2011; Duarte et al., 2013).

The province of Salta, in northern Argentina (which represents 6% of the national territory), has been identified as one of the provinces with greater potential for biomass exploitation (GENREN, 2007; Meisen and Gutiérrez, 2009). Its main advantages can be found in its great surface covered by native forests (23% of the national total), and the great diversity of natural ecosystems (evident by the changes in altitude, latitude, exposure and microclimate), that allow for different production activities. However, at the moment, there is only one operating biomass project of 40 MW in a sugar refinery (San Martín de Tabacal, which relies on the bagasse of sugarcane), and of all the projects tendered by GENREN, none of them have been awarded to the province (Grassi, 2012; James, 2012; Bondolich, 2012). On the other hand, two situations of conflict appear: i) a growing energy demand in the province (and fossil dependence) which follows national trends[5] —energy consumption between 2005 and 2010 grew 38%, while the number of users rose 17% (ERSP, 2011) — and, ii) strong pressure on native ecosystems for their conversion to cultivation (in advance of the agricultural frontier), or forestry exploitation (wood or fuelwood) (Paruelo et al., 2011) with no technical management planning. This has caused forests to rapidly shrink in surface area and in quality, in the last years —almost 330,000 ha have disappeared in 5 years (REDAF, 2012) — affecting quantity and quality of existing natural reserves, and the resulting ecosystem services and genetic pool derived from them (MEA, 2003; Paruelo et al., 2011). To add to this situation, the great majority of biomass residual resources generated in the province have not been incorporated into management planning (creating local sources of contamination). There is no accurate data on its particular characteristics or its energy potential.

This scenario is repeated, not only in other provinces of the country, but also in other regions of Latin America and the world (mainly developing countries), where the biomass (which is widely available in different types[6]) still has not been integrated into a territorial energy plan. The existence of rural population, growing energy demand, strong pressure on native forests, and waste generated by primary and secondary productive activities that are not used, are common elements in the above-mentioned territories. It is, therefore, of fundamental importance to study and evaluate, through a territorial approach, the main resources of biomass (and their physical, chemical and energy

[4] The reasons why some RES have been left vacant are uncertain, including waste of geothermal, solar thermal, and biogas energy. All of them are found in abundance in the province. Tidal power, for instance, was not included in the tender (James, 2012).
5 The national energy demand is rising (it has grown 40% in 10 years, reaching 115,735 GWh in 2010.
6 Probably, the sites with less presence of biomass are deserts and arid zones of the world.

characteristics) that could be used in strategic bioenergy systems in each region. The knowledge and definition of scopes and limitations of available biomass feedstocks, will contribute to an international effort to promote the RES. Most importantly, this will allow the creation of bioenergy projects that are realistic and suited to the demand possible, thereby promoting efficient use of the resources and making positive local impacts (Ladanai and Vinterback, 2009; IRENA, 2013). This was the objective of the present study that was carried out in the Lerma Valley (in the center of the province) where the Capital of the province of Salta is located. We have examined, identified, characterized and quantified biomass feedstocks availability, and its energy supply, studying the demand and utilization alternatives, with a territorial approach. This methodology could be applied to other geographical regions, within programs of territorial energy planning, and data generated for each resource (agricultural waste, municipal solid waste, wood waste) may be useful for other regions where these resources are present. Likewise, the main bottlenecks for exploitation of biomass resources in the province and the region are identified, proposing some possible strategic solutions.

2. Materials and methods

2.1. Study area

The Lerma Valley is divided into 7 region and 13 municipalities. It represents 3.2% of the territory of the province of Salta, but holds 53% of its inhabitants (almost 600,000 people) (INDEC, 2011). It is considered a unity or a region, due to its productive, ecologic, and climatic characteristics. It is a favorable area for agricultural and cattle ranching activities. The tobacco production regulates the economy of the region (Virginia and Criollo variety). Other crops, to a lesser extent, are: bean, horticulture (pepper), and fodder crops (alfalfa, corn, barley, and sorghum). The cattle's ranching is doing without management practices.

The climate is subtropical with a dry season - between humid and dry in tropical areas, according to Martyn (1992). The annual medium precipitation fluctuates between 600 and 800 mm and the annual medium temperature is approximately 16°C (Arias and Bianchi, 1996). The precipitation – concentrated from November to March- decreases towards the South, by altitude and exposure effects. The total surface area of the Valley is 5,000 km^2 (Núñez et al., 2007) with a maximum length of 144.3 km and maximum width of 52.3 km. It is located between the coordinates 24º22.0' to 25º43.0' South latitude and 65º15' to 65º 48' West longitude. Two regions are noted: i) the flat area, which belongs to an extended plain within the Valley with a medium gradient of 1%, which is suitable for agriculture and where urban and service centers are concentrated up to 1,600 meters above sea level (m.a.s.l.), and ii) the mountain area, that goes along the Valley (> 1,600 m.a.s.l.), with maximum altitudes of 5,000 m.a.s.l. to the West and 2,000 m.a.s.l. to the East, where a disperse population predominates. This population is devoted to self-consumption and extensive cattle ranching practices. 70% of the Valley population is located in the plain area (urban), while the remaining 30% can be found in the mountain area (rural).

2.2. Study design

The main vegetation units and types of land cover in the Lerma Valley were studied, tested, and quantified based on Landsat 7 Satellite images, technical survey of the ground, and processing of the information through a Geographic Information System (GIS) and the IDRISI Software™. For identification of local energy demand and available biomass (AB), work was carried out through surveyal of the documentary data, workshops (5), key informant interviews (40), and surveys (100). Workshops and interviews were the basis for the survey design. In the surveys, information was collected based on data from the production, quantity and types of existing resources in the Lerma Valley and their characteristics, resource management, types of services, main generated wastes, energy demands and consumption, types of fuels used, and others. With the gathered information, all existing resources in the area (potential biomass, PB) and main energy demands were listed. The AB was estimated as the fraction of the PB that was not currently used for other ends (compost, craftwork, fallow land), and which did not impose legal (ownership rights) or environmental restrictions (steep slope, protective forests, fragile or vulnerable area). Only this AB was studied through field sampling and the samples were characterized in the laboratory. The selection and analysis criteria established on the basis of relevant literature (Karekezi et al., 2004; Tsoutsos and Stamboulis, 2005; Ladanai and Vinterbäck, 2009; Angelis-Dimakis et al., 2011; Akbulut, 2012; Becker and Fischer, 2013; Sardianou and Genooudi, 2013) and on reflection to define the AB resources were: stock (quantity of resources in weight or volume), expectation (what is the probability that the generating source of the resource will continue to exist), estimate (interest in the use of the resource or social acceptance), requirements (legal and physical accessibility), effects (local impacts of its use), spreading (geographic concentration of the resource), and balance (generation rate of the resource)(see further details in Manrique et al., 2011). The AB resources studied were: i) dry biomass waste (including Criollo tobacco, Virginia tobacco, and pepper wastes), ii) wet biomass waste (comprising MSW), and iii) woody biomass. The latter included the three main ecosystems of the area: Yungas, Chaco, and Shrubland (Cabrera, 1994). The biomass and bioenergy potentials could vary between species of each ecosystem, so four species of the Acacia gender from the Shrubland were selected for its study. This choice justifies itself with the fact that this environment has traditionally been exploited for fuelwood use, as it occupies an important area of the Valley, presenting a scarce variety of woody species easily identifiable, and is an environment of easy access since it is distributed along the entire plain area. The other environments were studied with no differentiation of species (making an estimate of biomass per ecosystem). In view of the general characteristics common to the entire territorial unit, the samples of biomass categories listed above were collected in the center of the Valley (municipality of Coronel Moldes), and they are described in depth below.

2.3. Sampling of AB resources

- *Agricultural Waste Biomass (AWB) of Virginia and Criollo tobacco and pepper*

The random sampling covered 10% of the cultivated surface and consisted of collecting the entire plant before harvesting, at ground level, and using two situations: when the crop was growing close to the time of cutting down the plants, and after cutting down the plants – stocks or heaps – moments before its harvest. Once the plants were cut down, we obtained their total fresh weight, and the fresh weight of the product (useful part of the crop) and the waste fractions (stem). The samples were stored in bags, labeled and taken to the laboratory for analysis. 75, 50, and 35 plants of Criollo tobacco, Virginia tobacco, and pepper, respectively, were collected. The sampling intensity was defined according to the observed variability in the dry weight values obtained in the laboratory for each crop.

- *Woody Biomass of Acacias (WBA)*

A random sampling was carried out, with a pre-sampling of 20 rectangular parcels (90% probability, 20% error) of 100 m^2 (20 m by 5 m) in the dry season. The total number of samples was 35 parcels. The species studied were: *Acacia aroma* Gillies, *A. caven* Molina, *A. furcatispina* Burkart, and *A. praecox* Griseb. Of all the individuals in the parcels of ≥ 1 cm dbh (diameter at breast height to 1.30 m) and ≥ 50 cm height, the following was measured: dbh (cm) or diameter to base; mean crown ratio (m), total height (m), number of stems per tree and number of individuals per parcel. Diameter tape and graded woodland sticks were used. From each species in the parcel a small sample of branch of ≤ 2.5 cm was taken for analysis. All the samples of the same parcel made a sample composed by parcel and by species, which were weighed and taken to the laboratory.

- *Municipal Solid Waste (MSW)*

Unlike the rest of the feedstock categories, there are in the province, some useful data of MSW samples that were used for the estimates made (Raposo, 2003; SAyDS, 2004, 2009; González, 2010). Other necessary, but lacking data was collected from interviews of key informants and from direct observation.

2.4. Sample characterization

- *AWB feedstocks*

Samples were dried in stoves at 105ºC ± 2ºC until constant weight was obtained. Carbon (total) was determined through the Walkley-Black method and ash content was determined by gravimetry to 500ºC (for 6 hours). An average of the determinations for each crop was calculated. With the samples ground and flattened to form 1 g pills, the Upper and Lower Heating Value (UHV, LHV) was determined, using a Parr 1108 Oxygen Combustion Bomb. Five repetitions of the test were performed for each crop, and the average values were expressed in dry and wet bases. Finally, Nitrogen (total) was determined through the micro-Kjeldahl method, since it is an important indicator of the amount of nitrogen toxic components that can be formed (Munalula and Meincken, 2000). In the same way, when relating it to carbon (C/N relation), the aptitude of the resource for the alternative elaboration of compost can be found (Ochoa Hueso et al., 2013).

- *WBA feedstocks*

Samples were dried in stoves at 105ºC ± 2ºC and subsequently ground. The following tests were carried out: immediate analysis (humidity and ashes), elemental analysis (C and N), and thermochemical analysis (UHV and LHV), with five repetitions in each case. Methods employed are identical to what has been described for AWB.

- *MSW feedstocks*

MSW was characterized with the identical aspects to the ones mentioned for AWB. The average per capita waste generation is 0.6 $kg.day^{-1}$. For a total of 110,000 inhabitants (not including the population from the Capital that have sanitary landfill), there is a daily generation of 66,000 $kg.day^{-1}$ of MSW, or 24,100 $t.yr^{-1}$ (in wet weight). In the province, waste disposal is carried out through an open air discharge in almost all communities (alongside roads or in river beds) or in precarious landfills, with no waterproofing and without an appropriate technical design (except for the Capital city). Actions are currently being taken to eradicate such garbage dumps (SAP, 2013) and there is a provincial project for the creation of a regional sanitary landfill for the Valley that has not yet been put into practice (SAyDS, 2009). For these reasons, the main use of MSW would be biogas generation for energy purposes from the future regional sanitary landfill.

2.5. Biomass and Bioenergy estimates

- *AWB available*

The indexes the Table 1 were employed to estimate the AWB (Puigdevall and Galindo, 2007; SAGyDR, 2008; UIS, 2012; Long et al., 2013). The Crop Productivity Index (I_{CP}) was obtained with average productivity per area ($kg.ha^{-1}$). For tobacco, the averages obtained for campaigns 94-95 to 08-09 were used (Corradini et al., 2005; MEP, 2005 and

COPROTAB, com.pers[7]). For pepper, data was collected from farmers' interviews and COPROTAB. The Waste/Product Index (I_{WP}) is waste generated per product unit (kg.kg^{-1}). That is to say, the non-usable fraction of the crop. These values were obtained in the laboratory (drying) from the samples collected from field work. The total cultivated area (ha) was calculated of the average of the last three farming campaigns in each case. The total biomass waste was estimated (in kg) as the product of I_{CP} for I_{WP} and by area. It was considered that 100% of biomass waste could have been used. If there were restrictive factors in use, the relevant factor of discount should be applied. Finally, the potential energy available in the region was calculated as biomass for the $LHV_{20\%}$ (kJ.kg^{-1}). An average value of the three crops (dried in the sun) was used.

- *WBA available*

The above-ground tree biomass (AGB) of Acacias was estimated with the allometric equation of Parra Valdés (2001) designed for *Acacia caven* in a location in Chile which is similar to the area we are studying (Table 1). The biomass of the bole (that was estimated using the equation above mentioned) involves between 35 and 40% of total AGB. For this reason, the bole biomass was estimated and to this value was added 60% to estimate total AGB per tree. The AGB was calculated in the parcel and the value was extrapolated to hectare. In order to compare the fuel characteristics of the four species, the Fuelwood Value Index (FVI) was estimated (see Table 1), following to Purohit and Nautiyal (1987). The basic density values of the species were determined from available literature (Vita et al., 1998; Bravo et al., 2006; INTI-CITEMA, 2007). Ash content and the LHV estimated in the laboratory were expressed in wet base (20% humidity). For the bioenergy calculation, the MAI (Mean Annual Increment) proposed by FAO (2009) of 3% of total biomass stock (minimum productivity) was used. It was considered that from the stock of AGB, only one fraction is actual wood energy, so the AGB was reduced through a Woodfuel Fraction Factor (WFF). This WFF indicates the portion of the biomass total on the ground that consists of main branches, boles and bark, but excludes leaves and twigs. A factor of 0.83 for broad formations (FAO, 2009) was used. It was considered that 100% of annual growth of vegetation could be exploited for energy generation. Usage intensity as well as management practices are both the main characteristics that will distinguish the management of these species from the joint management of the other environments of the area. We used an average $LHV_{20\%}$ of the four species.

Table 1 Methods summary applied to estimate biomass and bioenergy for each studied biomass resource.

Biomass	Method	Description and units
AWB	$\mathrm{E} = \mathrm{I}_{CP} \times \mathrm{I}_{WP} \times A \times B \times LHV$	E= potential energy of AWB (GJ); I_{CP}=Crop Productivity Index (kg.ha^{-1}); I_{WP}=Waste/Product Index (dimensionless) A= area (ha); B= total biomass waste (kg); $LHV_{20\%}$= Lower Heating Value (kJ.kg^{-1}).
WBA	$\mathrm{Ln}\ \mathrm{Y_f} = 1.3999 + 1.7316\ \mathrm{Ln}\left(MCD^2 \times \mathrm{H}\right)$ and	Yf = dry weight of the bole (kg) or BB; MCD= Mean Crown Diameter (m); H= total height (m); AGB=above-ground biomass (t.ha^{-1});

[7] COPROTAB (Tobacco Producers Sector).

	$AGB = BB + (BB \times 0.6)$ and $FVI = (LHV \times \delta).(Z \times W)^{-1}$ and $E = AGB \times MAI \times WFF \times LHV$	BB=bole biomass (kg); FVI=Fuelwood Value Index (dimensionless); $LHV_{20\%}$=lower heating value ($kJ.g^{-1}$); δ= basic density ($g.cm^{-3}$); $Z_{20\%}$= ashes ($g.g^{-1}$); $W_{20\%}$= humidity ($g.g^{-1}$); MAI= Mean Annual Increment (% of AGB); WFF= Woodfuel Fraction Factor (dimensionless); E= potential energy of WBA (GJ).
MSW	$E_{CH4} = [(MSWt \times MSWf \times Lo) - R](1 - OX)$ Where: $Lo = MCF \times DOC \times DOCf \times F \times (16/12)$ and $E = E_{CH4} \times LHV$	E_{CH4}= methane emission (Gg[8]$.yr^{-1}$); MSWt=total MSW generated ($Gg.yr^{-1}$); MSWf=MSW fraction eliminated in landfill; R=recovered methane ($Gg.yr^{-1}$); OX=oxidation factor (fraction); Lo= potential of generation of methane ($GgCH_4$. $GgMSW^{-1}$); MCF=Methane correction factor (fraction); DOC=Degradable organic carbon (fraction); DOCf=Fraction DOC dissimilated; F=Fraction of methane in LFG; 16/12= conversion from C to CH_4. LHV=lower heating value ($kJ.\ mN^{-3}$); E= potential energy of MSW(GJ).
WBE	$Y = \exp^{\{-2.4090 + 0.9522 \times \ln(D^2 \times H \times S)\}}$ $Y = 0.112 \times (\rho \times D^2 \times H)^{0.916}$ $BF = 0.1368(D^2 \times H)^{0.7559}$ and $E = AGB \times MAI \times WFF \times LHV$	Y = tree biomass (kg); D = diameter at breast height or dbh (cm); ρ and S = wood density ($g.cm^{-3}$); H = total height (m); BF = biomass of main stem (kg); $LHV_{20\%}$ = lower heating value ($kJ.kg^{-1}$); AGB=above-ground biomass ($t.ha^{-1}$); MAI= Mean Annual Increment (% of AGB); WFF= Woodfuel Fraction Factor (dimensionless); E= potential energy of WBE (GJ).

where: AWB: agricultural waste biomass; WBA: woody biomass of Acacias; MSW: municipal solid waste; WBE: woody biomass of ecosystems. See references in the text.

- *MSW available*

The MSW energy potential was calculated indirectly, estimating available energy from the biogas or landfill gas (LFG) that could be generated if these MSW (which have a humidity content of 50%) were used in the regional sanitary landfill. Unlike the rest of the feedstocks, the annual generated tons are counted, but without deducting humidity content, since it is one of the factors which will promote the anaerobic digestion process and biogas generation. Biogas generation was estimated through the Triangular Method proposed by Kumar et al (2004) which is based on a modification of the IPCC Default Method, developed by Bingemer and Crutzen (1987) and used in the Revised IPCC (1996)

[8] 1 $Gg.yr^{-1}$= 1000 tonnes yr^{-1}.

guidelines as the default methodology for estimating methane emissions from MSW disposal sites. The Triangular Method assumes that released biogas responds to a kinematic equation of degree one in a triangular form, where the area of the triangle might be equivalent to the gas released in the period, since each ton of solid waste is placed. This area (gas volume) is assumed equal to the volume computed using the IPCC Default Method. The value of 'h' (point) of methane (CH_4) emissions was calculated knowing the gas volume and the triangle base, and then the other values were calculated. A useful life of 15 years of landfill was assumed (Kumar et al., 2004). The variables and values employed were: methane correction factor (MCF = 0.6); fraction of degradable organic carbon (DOC= 0.13 $kg.kg^{1}$ MSW); fraction of non-assimilated DOC (DOCf =0.77 $kg.kg^{-1}$ MSW); fraction per volume of CH_4 in biogas (F = 0.5) and 16/12= conversion from C to CH_4. Given the great amount of organic waste from the MSW of the Valley (more than 60%) the equation was modified as A= fraction of paper in the MSW, and C= fraction of cooking waste, resulting in DOC= (0.4A) + (0.15C) =0.13. For DOCf, for T= temperature in the anaerobic area of the waste, considered as 35ºC (Tsai et al., 2007), the value of 0.77 is deemed as follows: DOCf= 0.014T+0.28= 0.77. For MSW generation projections, the average annual demographic growth rate of the Valley regions corresponding to the decade 1991-2001 (MCS, 2004), whose value is equal to 1.67% (INDEC, 2011) was used. LHV of biogas of 18,800 $kJ.mN^{-3}$ (Zhang et al., 2007) was assumed.

- *Woody Biomass of Ecosystems (WBE) available*

Ecosystems AGB data (expressed as oven-dried tons per hectare) was published in Manrique et al. (2011), whose estimations are based on a total survey of 69 parcels (90% probability, 20% mean standard error) and allometric equations (of Brown et al., 1989; Chave et al., 2005 and Zhou et al., 2007 for Yungas, Chaco and Shrubland, respectively) (Table 1). MAI values for studied ecosystems are scarce at the country level. Considering the available references, we worked with a MAI of 2 $t.ha^{-1}.yr^{-1}$ for Yungas, 1 $t.ha^{-1}.yr^{-1}$ for Chaco, and 0.5 $t.ha^{-1}.yr^{-1}$ for Shrubland, meaning 1.31%, 1.64% and 2.77% of AGB stock estimated for environment (lower than those proposed by FAO, 2009). A WFF of 0.88 was applied for Yungas and 0.83 for Chaco and Shrubland (FAO, 2009). An usage factor from MAI of 70% (Brassiolo et al., 2007) was considered. The $LHV_{20\%}$ (14,630 $kJ.kg^{-1}$) was obtained as the average suggested in the literature and international data bases. Data of wood density were obtained from the database compiled by INTI-CITEMA (2007).

3. Results and Discussion

3.1. Potential and Available biomass resources in the Lerma Valley

We recognized different categories of PB resources per area (Fig. 1). In the mountain area we found: natural biomass (fuelwood) of the Yungas ecosystem, AWB (from subsistence activities), cattle ranching wastes not stabled and MSW. In the lower area there is a greater diversity of biomass sources. In addition to the above-mentioned, environments of Prepuna (sparse vegetation of mountain hillsides and grazing lands), and other forest lands (shrublands and scrubland) were detected. The main crop groups that occupy 60,000 ha are: industrial plantations (basically, tobacco, with 26% of the area), pulses (several varieties of bean, with 22% of participation), perennial crops (alfalfa, Buffel Grass, Gatton Panic, white and red clover, other pure and consociated perennials), and annual forages (oats, barley, forage sorghum, and melilotus) occupying 18% and 15% respectively; grain cereals, fruit trees and vegetables crops (18% of the total area). Animal waste biomass, only considered in stabling production condition could be constituted as a resource with energy potential. However, in the Valley there are 90,000 head of cattle (bovine cattle represent more than 63%) but only some farmers have stabled cattle. As for the industrial sector, the activities are: tobacco products, food and beverages, publishing and printing, chemical substances and products, and non-metallic minerals -borates and salts) (MEP, 2005). Manufacturing activity is concentrated in the Capital region (92% of the Valley regional industrial facilities). Other resources existents are the MSW, with greater annual generation volume than in the higher area. Punctual biomass sources were not considered since it will only be possible to exploit them on a land scale.

It is important to mention that every biomass category has its own features. For instance, AWB varies in volume according to the occupied area by each variety, the useful fraction of each plant, the level and type of usage. The annual or perennial forage used for pasture, for example, does not generate waste material that could be utilized for energy purposes. On the other hand, the crops show fluctuations in annual production, in seasons and years (which also implies fluctuations in available waste). All these aspects (detailed in item 2.2) defined the resources considered as AB, which will be studied in depth below. Firstly, this paper makes reference to the potential (quantity and energy) of the resources, and secondly, it analyzes the scope of coverage of the main energy demands of the Lerma Valley. The characteristics of each of the studied resources are shown in the Table 2.

Table 2 Main characteristics of the studied biomass feedstocks.

Feedstock	Humidity (%)	$LHV_{20\%}$ ($kJ.kg^{-1}$)	C (%)	N (%)	Z (%)
Criollo tobacco wastes	20-30%	10,522±118	45.22±0.14	2.25±0.01	9.5±0.03
Virginia tobacco wastes	20-30%	10,778±121	46.11±0.12	1.89±0.01	7.7±0.02
Pepper wastes	18-22%	10,248±115	46.05±0.12	1.01±0.00	4.8±0.00
Annual Acacias biomass	28-33%	13,745±60	47.68±0.13	1.02±0.00	3.7±0.03
MSW (biogas)	48-52%	8,360±14%	38.32	0.84	n.d.
Annual Chaco biomass	18-23%	14,630±12%	50	n.d.	n.d.
Annual Yungas biomass	20-25%	14,630±12%	50	n.d.	n.d.
Annual Shrubland biomass	18-23%	14,630±12%	50	n.d.	n.d.

$LHV_{20\%}$ is the lower heating value with 20% of humidity ($kJ.kg^{-1}$). For LHV, C, N, Z are showed average ± standard deviation (or percentage of deviation).

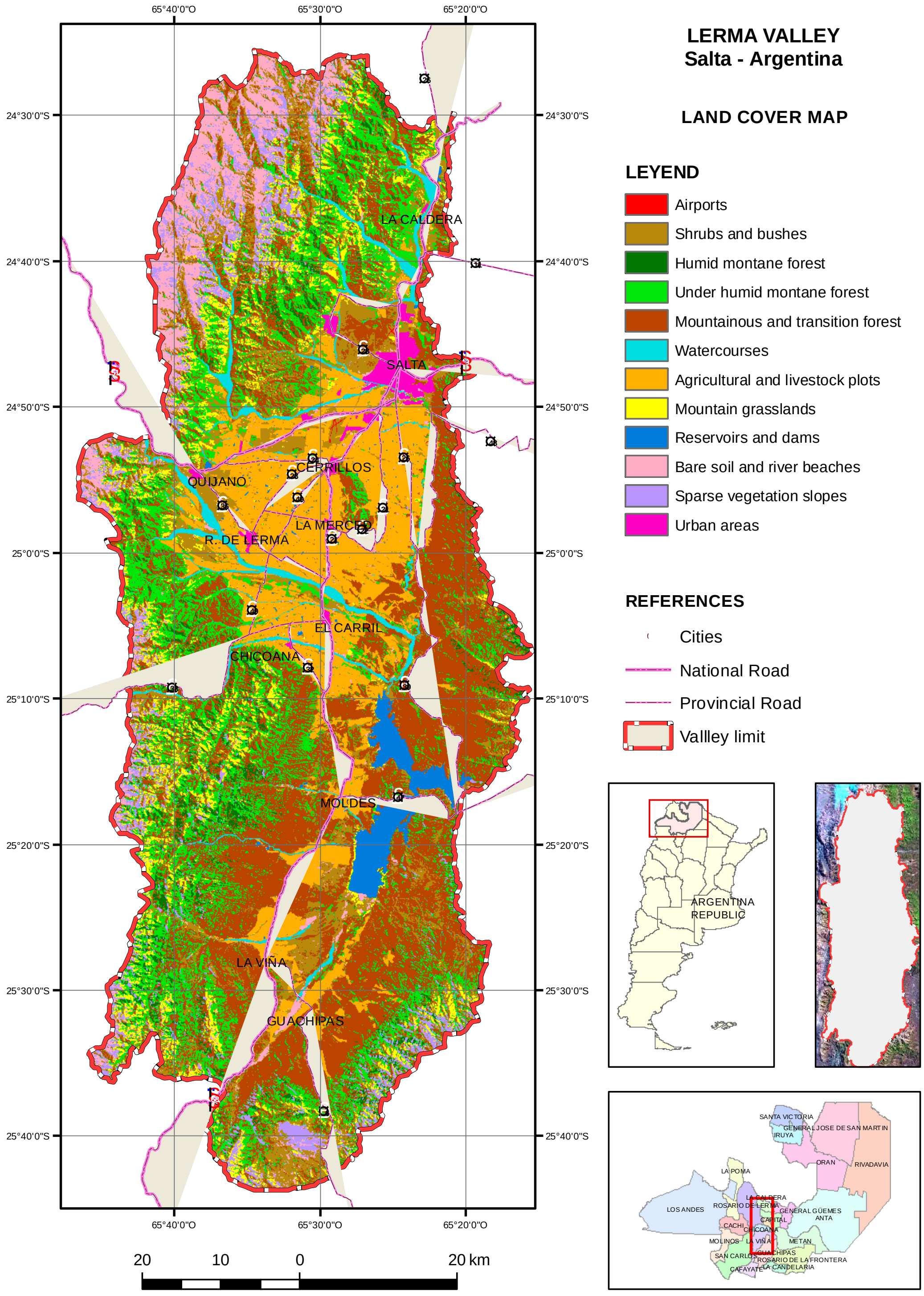

Fig. 1. Land cover classes of Lerma Valley (Salta, Argentina).

3.2. Biomass and Bioenergy of the studied resources (AB)

- *AWB supply*

Energy potential is shown in Table 3. Considering an average I_{WP} of 0.5 for Criollo, 0.49 for Virginia Tobacco, and 0.68 for pepper, for an average area and yield (1,800 kg.ha^{-1}, 2,100

$kg.ha^{-1}$ and 1,600 $kg.ha^{-1}$, respectively), the annual AWB generation is of approximately 18,000 t of dry weight (around 16,000 t of Virginia Tobacco, 600 t of Criollo Tobacco, and the rest, pepper). The generated waste represents an energy supply of more than 206,000 $GJ.yr^{-1}$ gathered in a 4-month period, where 93% of this value is provided by tobacco. In particular, Virginia Tobacco comprises more than 89% of this supply. Nowadays, these wastes are a hindrance to the area and generate local contamination.

- *MSW (biogas) supply*

If we consider that biogas fraction that can be energy valuable from a sanitary landfill (70%), the average generated volume would be 140 $m^3.h^{-1}$, with a range of 5 to 245 $m^3.h^{-1}$, from the first year up to the last year of the series (for 15 years). The generation would be 1.9 million m^3 of average annual biogas. The energy potential of this biogas would be on the average of 34,000 $GJ.yr^{-1}$ (Table 3). The estimation of biogas production in sanitary landfills at the capital municipality, aims the generation of CERs (Certified Emissions Reduction) to the Clean Development Mechanism (MCS, 2004). Presently, official sources assess that it is the only CDM within the Kyoto Protocol that the World Bank continues supporting in the Argentine Republic (MCS, 2013).

- *WBA supply*

The average AGB of the four species is 9.14 $t.ha^{-1}$. Considering WFF and productivity, the woody supply of the four species (MAI) is 15,500 $t.yr^{-1}$ (100% of usage factor). The $LHV_{20\%}$ fluctuates from 12,993 ± 55.6 $kJ.kg^{-1}$ (*A. praecox*) to 14,274 ± 63.5 $kJ.kg^{-1}$ (*A. caven*). The FVI states that the two species with best fuel qualities are: *A. aroma (FVI=1,748)* and *A. caven (FVI=1,609)*, placing *A. praecox (FVI=1,274)* last. This concurs with Vita et al (1998) and Parra Valdés (2001) which mention the excellent wood and charcoal quality of *A. caven*, as well as of *A. aroma* (Bravo et al., 2006; Pometti et al., 2009). Considering the average of AGB and LHV, they are close to 213,000 $GJ.yr^{-1}$. The estimation data can be seen in Table 3. The current biomass could be managed as an *opportunity crop* (use of the annual biomass generated at the site were the species grows, in this case, generally soils with scarce or null productive value), and on the other hand, it would be possible to restore and recover degraded and unproductive soils with these species by producing *dedicated energy* crops (growing the Acacias for soil recuperation and bioenergy simultaneously).

Table 3 Annual biomass and bioenergy supply of feedstocks studied in the Lerma Valley.

Feedstock	Area (ha)	Biomass ($t.yr^{-1}$)	Unitary Energy ($GJ.t.^{-1}$)	Bioenergy ($GJ.yr^{-1}$)
Criollo tobacco wastes	720	655	10.5	7,115
Virginia tobacco wastes	15,475	15,924	10.8	173,060
Pepper wastes	1,120	1,218	10.2	25,800
Annual Acacias biomass	68,000	15,476	13.7	213,000
MSW (biogas)	100,000	24,100	8.3	34,100
Annual Chaco biomass	140,000	81,373	14.6	1,190,480
Annual Yungas biomass	91,300	111,987	14.6	1,658,370
Annual Shrubland biomass	68,000	4,223	14.6	61,780
Total		254,956		3,363,409

MSW are considered as biogas and the annual generated tons including the humidity content. For Shrubland environment, a biomass value is considered which deducts the contribution of the Acacias and its energetic value. Yungas only includes the lower area up to 1,400 m.a.s.l (83% of the total area).

- *WBE supply*

The AGB of each environment is: 152 $t.ha^{-1}$, 62 $t.ha^{-1}$ and 18 $t.ha^{-1}$ for Yungas, Chaco, and Shrubland, respectively. The three environments represent more than 63% of the total surface of the Valley, being Chaco 28% (140,000 ha), Yungas 22% (110,000 ha) and the rest Shrubland (68,000 ha). The area of Yungas mentioned in Table 3 reaches 83% of this environment (up to 1,400 m.a.s.l., altitudinal limit of sampling). The amount of fuelwood that could be obtained with a 70% usable factor would be 200,000 $t.yr^{-1}$ (56% coming from Yungas, 41% from Chaco, and 3% from Shrubland). This is directly related to the surface occupied by each environment, but also to the amount of biomass per ha (in tons of dry weight). In the case of Shrubland, the annual supply of biomass was calculated at 4,223 $t.yr^{-1}$ (Table 3) deducting the supply of the four Acacia species (15,476 $t.yr^{-1}$) from the total supply of fuelwood (20,000 $t.yr^{-1}$). This supply will only be available in a sustainable manner if the ecosystems are subjected to management planning since, in all cases we found degradation signs (Montenegro et al., 2005; Paruelo et al., 2011; REDAF, 2012).

3.3. Total supply from the available biomass

From the total AB ($t.yr^{-1}$), AWB provides 7%; MSW contributes more than 9%; and the woody biomass sector, the remaining 84% (Yungas and Chaco are the ones that contribute most to this value). In energy terms, the percentages are similar (Fig. 2). The most significant change can be observed for MSW, which in its contribution of annual tons of material, represents more than 9%; in terms of bioenergy they only provide 1% of the total. The main reason for this difference lies in the fact that all biomass materials considered are expressed in tons of dry weight; while in the case of MSW the annual contributions of material do not have the humidity value deducted. In energy terms, their relative contribution is low (since a big part of the calorific value is lost when the humidity contained in these wastes is evaporated), but in absolute values, the energy potential is useful and could bring local benefits. The fundamental role played by the ecosystems in the area as wood-fuel suppliers (because of its availability, accessibility and cost-free) should be protected not only including them in plans of management and territorial planning but also of control mechanisms. The energy potential of these ecosystems is evident, but undoubtedly, the lack of control mechanisms could entail an overexploitation of the resources and the imbalance or loss of the ecosystem functions that they perform (MEA, 2003; Montenegro et al., 2005). Despite the existence of a strong cultural factor in the exploitation of the "fuelwood" in the area, there are also physical and economical restrictions that prevent exploitation of other fuel sources (fossil) that should be addressed with appropriate political measures (distances, costs or lack of infrastructure and of logistics).

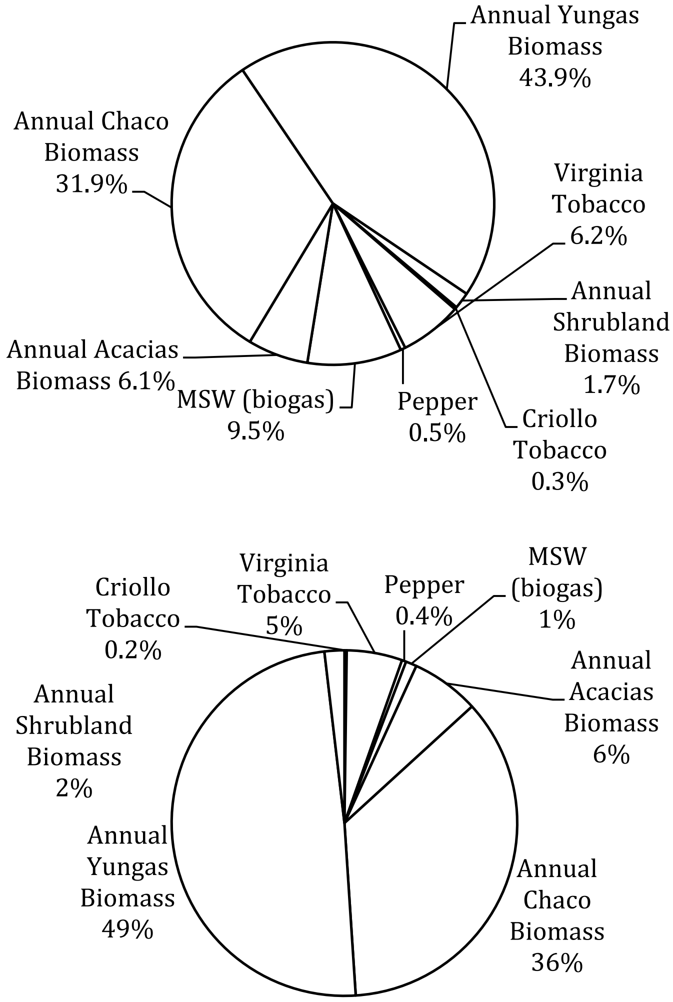

Fig. 2. Contribution (%) of feedstocks studied in the Lerma Valley (Salta) to the annual biomass ($t.yr^{-1}$) and bioenergy ($GJ.yr^{-1}$) (top and bottom, respectively).

3.4. Energy demands and scopes of coverage

For the lower area of the Valley, 48% of the population agrees to point out that the main energy demand is thermal (process heating, mainly), followed by electrical energy demand (29%), and mechanical or self-propulsion energy demand (23%). For the mountain sector, thermal energy generation has 86% of importance within the possible biomass applications (cooking 52% and heating 34%). Considering the calculated energy potential and needs of the population, a few estimations were made in order to observe the scopes and limitations of the available bioenergy.

- *Fuelwood demand per household*

The annual biomass of Yungas (fuelwood) is the main fuel source available to the higher sector (33,000 people). Considering a fuelwood consumption of 3.6 $kg.inhab^{-1}.day^{-1}$ (INTA, 2003) the demand would be 43,300 $t.yr^{-1}$, which is equivalent to almost 635,000 $GJ.yr^{-1}$ ($LHV_{20\%}$ = 14,630 $kJ.kg^{-1}$). The annual supply of Yungas is 2.5 times higher, that is why, with the naked eye, this demand could be assumed to be covered. However, it must be considered that the population of the Capital region (84% of the Valley) is not included in the calculations, and probably lumber, farming (tree clearance) enterprises, small and medium industrial usage, productive processes, or others, also put pressure on this environment. The lower area has access to a natural gas pipeline network (although still with insufficient coverage), or points of sale of gas cylinders, therefore, they were not included in the estimations.

- *Fuelwood demand for production processes*

The drying of tobacco in drying barns (Virginia variety, since Criollo tobacco is dried in the sun) is one of the most fuel demanding activities of the area (either with fuelwood or gas). Based on the interviews, it is known that almost 235 people use fuelwood in their drying barns (of their own or rented) (MEP, 2005) and that 8 m^3 of fuelwood are used per "estufada"[9] to dry 2 ha of tobacco. The total tobacco production (leaving out other factors) is related to the cultivated area by the producer, so, the relations shown in Table 4 can be considered. The fuelwood demand in volume (70,520 $m^3.yr^{-1}$), will represent for each ecosystem in the area, a different weight according to the average density of the wood from the species found in that area (without consider the density bulk the transport, because the fuelwood is obtained in the proximate zone). Making an average per environment, the demand would be 55,400 $t.yr^{-1}$. It is odd to observe that fuelwood demand from the tobacco sector (0.21% of the Lerma Valley) that employs this resource in their drying barns is even higher than the fuelwood demand estimated for the whole higher sector (33,000 people) by almost 1.3 times. This demand could be covered theoretically with the fuelwood supply of the Chaco, although employing this fuelwood in its state found in the environment would almost exhaust its potential and it would affect its degradation condition even more. It must be taken into consideration that the interventions throughout history, had not practiced planned management of the wooded mass or scientific-technical criteria for its use, and its value and significance have not been recognized in specific legislation until very recently (Paruelo et al., 2011). For this reason, to meet the demand it is necessary to incorporate other local sources of heat generation different from the traditionally used fuelwood, such as AWB or the Acacias supply (with management). These alternative resources have great energy potential and strong ecological adaptation. The total biomass supply would be 33,200 $t.yr^{-1}$ from all these sources. And, with this supply, the pressure exerted on natural environments could be reduced, covering 60% fuelwood demand for drying barns. This substitution could be regulated on a provincial level since the tobacco activity counts on fiscal subsidies and benefits, and is a high yield activity. Managing specific species, that would be theoretically certified, would require a training period but would avoid the indiscriminate intervention on other species.

Table 3 Required firewood for the drying barns per producer category and total required firewood ($m^3.yr^{-1}$).

Nº of producers	Average cultivated area (ha)	Producers in each category (% of the total)	Number of people	Number of dried	Required firewood per cycle (m^3)	Required firewood per category ($m^3.yr^{-1}$)
235	10	5	12	5	40	480
	20	10	23	10	80	1,840
	50	45	106	25	200	21,200
	100	20	47	50	400	18,800
	150	20	47	75	600	28,200
TOTAL			235			70,520

[9]Number of times that the drying barns are loaded for the drying of the production.

- *Natural gas demand for productive processes*

Around 74% of the producers employ natural gas from the grid for their tobacco-drying barns. On a yearly basis, it could be replaced (according to the kind of producer) from 11% to 18% of natural gas (LHV= 36,800 $kJ.mN^{-3}$) used in the production units where only Virginia variety is produced. This means between 115 $GJ.yr^{-1}$ and more than 700 $GJ.yr^{-1}$ of fossil energy will be replaced by their own generated wastes. This variation is mainly caused by the difference in cultivated areas per producer (available waste biomass and fossil consumption are different). The following were used as average cases: producers with 10, 20 and 50 ha and for three average crop yields 1,800; 2,000 and 2,200 $kg.ha^{-1}$. In production units where both varieties (Criollo and Virginia) are grown, a 24% to 36% annual consumption of natural gas could be replaced (from 117 $GJ.yr^{-1}$ to more than 710 $GJ.yr^{-1}$) by available bioenergy from the generated agricultural wastes. The absolute values of energy replacement are similar if producers devote themselves to one, or both, tobacco varieties, but the replacement percentages are higher when the two varieties are combined. Another alternative to exploit these AWB could be to sell them to other producers, but to this date there are no markets or logistics developed in the area, hence, it is a hypothetical future scenario. Considering the price at which biomass is marketed – of similar characteristics – nowadays in Spain and other European countries (MNRC, 2011; AVEBIOM, 2013) of 0.10-0.15 $\$.kg^{-1}$ (Argentine currency), excluding transportation and VAT, and a gas unit price of 0,16 \$[10].m^{-3} to date, plus a monthly fixed cost of \$15,00 (Argentine currency), the option of selling waste to distribution centers for its subsequent energy use would be profitable for the producer, achieving economical savings from 10% to 30%. From the point of view of transportation distances and costs, the location of energy distribution and exploitation centers in the Valley (which has a total longitude of 140 km), could turn that activity into a profitable one (Meehan and McDonnell, 2010).

- *Electrical energy demand*

Taking the annual electricity consumption value per capita suggested by the National Atomic Energy Commission (NAEC, 2007), and used by the Secretary of Environment and Sustainable Development of Argentina (SAyDS, 2008) of 1,200 $kWh.yr^{-1}$ per capita (28% efficiency), it is estimated that the total available bioenergy from AWB, MSW, and WBA (Acacias), could meet the electrical demands of around 32,500 people. The estimations of electricity generation from MSW were calculated through the modified decomposition first-order kinetics method, as well as thermal and electricity capacity, year by year. Taking into consideration only the MSW and its biogas generation, there would be sufficient energy for the demands of 2,200 people, which means 2% of the total number of the Valley inhabitants (excluding the Capital), and almost 3% of the total number of inhabitants from the lower area. Using different operation times in a power generation plant (8, 16, and 24 operation hours), the resulting electricity output is shown in Fig. 3. The electricity generation output from these MSWs would range between 800 MWh and 3,500 MWh – from year 1 of sanitary landfill operation until year 15 – with the possibility of reaching 4,500 MWh in another 15 years. This biogas could be burnt for heat generation and to move steam turbo sets, or could be used in internal combustion engines. The thermal capacity level ranges from 1.32 MW to 1.66 MW, while the electrical capacity level varies from 0.4-0.5 MWe. The estimated numbers must be validated with new field evaluations. There are many variables involved in the electricity production that could vary the estimations: sanitary landfill characteristics, effectively valued biogas percentage, biogas calorific value, climatic conditions, among others (Kumar et al., 2004; Thompson et al., 2009; Akbulut, 2012). Nowadays, the Municipality has been installing monitoring

[10] US dollar currency exchange rate today (12/02/13): buy price US\$4.82- sell price US\$4.85.

equipment in the municipal sanitary landfill to get local information on the above mentioned aspects (MCS, 2013).

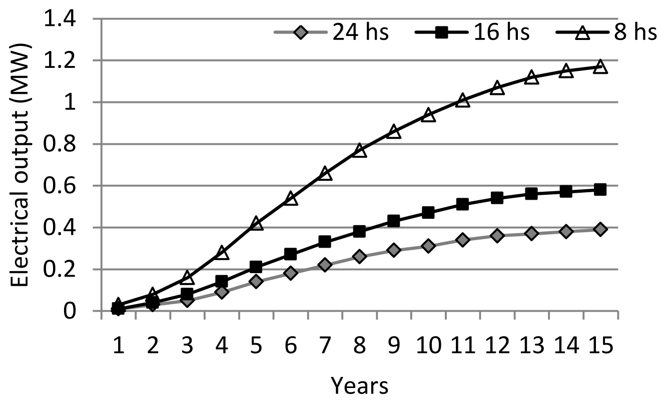

Fig. 3. Electrical output of a possible biogas based power generation plant, produced from a regional sanitary landfill projected for the exploitation of MSW of the Lerma Valley. Three possible scenarios are shown, based on the numbers of hours of operation of the projected plant (8, 16, 24 hs).

3.5. Some strategic options for the management of AB

Although there might be multiple AB applications, the analytical framework applied (Painuly, 2011) allows us to state that:

- AWB could offer energy and economic benefits by its use for heat generation to dry tobacco in drying barns or other necessary operations of the tobacco productive cycle, within the same production units where they are generated. Two options are available: substituting part of the natural gas demand, from the drying barns that use this fuel, or replacing part of the fuelwood demand, from the drying barns that work with this resource, and, in this way, decrease the indiscriminate pressure on the ecosystems. These applications could immediately be put into practice. The total of avoided emissions, using AWB for the replacement of one type of fuel at a time, would be from 13,500 $tCO_2.yr^{-1}$ (if only natural gas, measured in m^3, were to be replaced) to 17,800 tCO_2.año^{-1} (if oil, measured in liters, were to be replaced) (Manrique and Franco, 2012). This would be equivalent to mitigating the annual emissions from 2,300 to 3,100 Argentine citizens, considering their carbon footprint, which for Argentina is 5.71 t $CO_{2eq}.yr^{-1}$(SayDS, 2008).

- For MWS, using the biogas generated in sanitary landfills would be the most convenient option at the moment. Later, incorporating classification in the material origin for recycling and for decreasing waste volume could be thought about. MSW electricity output is low if considered only from the point of view of an economic investor. However, the correct treatment of this resource is far from being considered a business, but as a responsibility of municipalities and governments, where the general population is also included. The MSW contribution to the site of sanitary landfill construction, and the impact on the environmental health of the area, will be two advantageous factors. Furthermore, biogas use would mean a GHG emissions reduction of around 15,000 t $CO_{2eq}.yr^{-1}$ or a total of 225,000 t $CO_{2eq}.yr^{-1}$ in 15 years. MSW exploitation would make it possible to mitigate the emissions of 2,600 citizens a year (according to the carbon footprint).

- Acacias have great fuel qualities and high local tolerance and adaptation, since they are native species. Fuelwood obtained from these species could be allocated, along with AWB, to the caloric energy demands from the productive processes and, specifically, from the drying barns that work with fuelwood. The usage of annual WBA as energy would make it possible to avoid 15,400 to 20,100 $tCO_{2eq}.yr^{-1}$ (according to replaced fossil fuel), equivalent to the emissions of 2,700 to 3,500 Argentine citizens a year (Manrique and Franco, 2012).

- The AGB of Yungas could theoretically cover the caloric fuelwood demand from the high area. By achieving restrictions from free access to this environment (fines, penalties) and applying management planning, it would be possible to reduce pressure on their use and their degradation could be reverted, with all the subsequent ecosystem benefits (Costanza et al., 1997; MEA, 2003). Moreover, specific study of Acacias from Shrubland shows that each species offers a differential contribution to the environment biomass and bioenergy supply. It is necessary to conduct further research about the specific species present in each ecosystem, their MAI values and their ecologic behaviors, and long-term development of management and monitoring planning with the end product of not negatively affecting the natural biomass supply available from these ecosystems. The AGB of these three ecosystems (Yungas, Chaco and Shrubland – including Acacias-) could offer around 3,120,000 $GJ.yr^{-1}$ in the Valley. This supply would allow the prevention of 175,000 t $CO_{2eq}.yr^{-1}$, which is equivalent to the emissions of 30,600 Argentine citizens.

3.6 Outlook for bioenergy in the province

For these options of bioenergy exploitation to be viable in the province, it is necessary to work on some points that appear as bottlenecks for their implementation, and which are briefly listed below (FAO, 2009; Meisen and Gutiérrez, 2009; James, 2012; Fuchs, 2012; Fernández, 2012):

-Political-Institutional barriers: RES pricing distortion due to fossil source subsidies; energy and environmental policies not compatible in a unified long term plan (for instance, the Forest Law with the Energy Law); deficient mechanisms to control obeying current laws. Likewise, energy efficiency measures should be promoted in RES projects.

-Technical barriers: carrying out research to fill in the gaps in our knowledge and skills and provide the right information and training. It is necessary to precisely determine the energy offer and demand with specific research, so as not to overestimate or underestimate the bioenergy project potential (the continuity of supply is key to justifying the investment for equipment and the infrastructure needed for exploitation and/or security of the grid); to develop collection and storage logistics of waste resources (that due to their low energy density demand a resource generation ratio similar to, for instance, agricultural wastes); to develop and test local technologies strengthening national capacities and markets.

-Economical-Financial barriers: high initial investment and lack of mechanisms that are clear and lasting for financial support to local initiatives; difficulty in processing and high transaction costs, even for small scale projects; difficulty in the competitiveness of the projects due to the impact of certain subsidies. Business incubators could perhaps contribute in this instance, and in the province there are efforts to start working on this alternative. In the country, there is some politics to promote technological incubators and parks through FONTAR (Argentine Technology Fund), the ANPCyT (National Agency of Scientific and Technological Promotion of Argentina), or the AIPyPT (Special Program of Business Incubator Science Parks and Technopoles of the Secretary of Science and Technology of Argentina). However, there is still scarce agreement, with limited allocation of physical and human resources, and a low level of labor.

If the biomass of the Lerma Valley (with 2% of the provincial area) was to be managed based on scientific-technical guidelines, and exploited in energy processes (with a total contribution of 8 ktep.yr^{-1}), the bioenergy participation, at a national level (2,250 ktep.yr^{-1}), would be 0.36% higher than the current one. This shows a greater potential of biomass resources, each one considered within their own specific scope and limitation in the places where they are generated. The combination of different utilization projects of this type could be constituted with pilot tests of their performances, in the adaptation of proposals for each area, and, at the same time, would contribute to a common objective proposed by the national government. The study on a regional level will make suitable territorial planning. Furthermore, studied resources are not the only possible materials to employ. Following observed tendencies at an international level (Demirbas, 2009; Frac et al., 2010; Rajvanshi and Sharma, 2012; González García et al., 2012) there is great potential in resources such as microalgae, lignocellulosic residues and opportunity energy crops. There are still no results with these kinds of crops or exploitation in the province, and there are only a few experiences at a national level. Investigative efforts are headed towards these areas nowadays. In every case, the proposal of projects that, during their life cycle, contemplate the efficient use of the resources, and that close the cycle of the materials, will at the same time be valuable at meeting the national environmental, energy, and social responsibility commitments (for instance, the use of algae for energy generation from sewage effluents, or biogas from livestock wastes, among others). Such projects, run with a multi-disciplinary and open focus, as far as technical systems (such as biomass generation, production, and conversion) and social systems (actors and relevant politics, information spreading mechanisms) that intervene or that could intervene so that they are carried out, would undoubtedly be successful for the province and worthy of being repeated at a national level.

4. Conclusions

In the Lerma Valley, Salta, three categories of AB have been detected for their energy exploitation: AWB (including waste from Criollo and Virginia Tobacco, and Pepper), MSW and natural biomass (including three main ecosystems of the area: Chaco, Yungas, and Shrubland). With technically based management plans, and clear monitoring and control measures, the studied biomass resources could offer an annual energy supply of more than 3.3 million GJ.yr^{-1}, which is equivalent to 0.36% of current national biomass consumption. Of the total AB per year in the Valley (almost 230,000 t dry weight .yr^{-1} and 24,000 t wet weight.yr^{-1}) AWB represents 7%, MSW (as biogas) contributes more than 9%, and the sector of woody biomass provides the remaining 84%.

Although there are diverse possible applications for AB, the study and discrimination of population energy demands, and the potential energy base of the resources, made it possible to make realistic estimations. It is affirmed that there are specific bioenergy objectives which could be covered, as well as the need to give priority of use to each resource, so that the local energy demands can be met before the external demands. The use of total annual bioenergy supply from the resources studied would make it possible to avoid the emissions of 220,000 tCO_{2eq}.yr^{-1}.

The main barriers for detected implementations are political regulations, financing and support mechanisms, and the total lack of technical knowledge of the potentials and limitations of feedstock from biomass to a local level, and concrete results on different scales.

The contributions of this work can be identified in three main areas. Firstly, construction and development of a methodology of territorial approach for the identification, study and characterization of the main resources of biomass that could be used in potential bioenergy systems. This methodology can be applied to other geographical regions, within programs of territorial energy planning. Secondly, a new set of data of widely available biomass resources has been generated. This provides physical, chemical and energy data of biomass fuels, which are represented at the global level (agricultural waste, municipal solid waste, wood waste), contributing to expansion of the database in the same way. Lastly, scientific knowledge in the field of bioenergy and energy planning has been constructed and it will be useful to orientate the advance of the research in these fields.

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