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Pre-feasibility Study for the Development of a Biogas Plant

Estudo de pré-viabilidade para o desenvolvimento de uma planta de biogás

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Content

ABSTRACT:
This paper presents pre-feasibility studies for the installation of a Biogas Plant on a Campus of a University. The logistical planning includes the distance between the plant and the waste source. Biomass sources in the municipality are rice (182,435 tons per year) and maize (5,479 tons per year). There are also household organic waste (1,375 tons per year). With the logistic analysis that the transport of agricultural waste has not a restrictive character. As preliminary analysis was verified economic viability for agricultural residues and for organic Municipal Solid Waste.
Keywords: Biogas Plants, Energetic potential, Pre-feasibility analysis.

RESUMO:
Este trabalho apresenta avaliações de pré-viabilidade para a instalação de uma planta de biogás em um campus universitário. Foi realizado o planejamento logístico da distância entre a planta e a fonte de resíduos. As fontes de biomassa disponíveis no município são o arroz (182.435 t/ano) e o milho com (5.479 t/ano). Também há resíduos sólidos orgânicos domiciliares (1.375 t/ano) no local. Com a análise logística foi constado que o transporte dos resíduos agrícolas não tem caráter totalmente restritivo. Conforme análise preliminar foi verificada a viabilidade econômica, tanto para os resíduos agrícolas como para os sólidos domiciliares.
Palavras-Chave: Planta de Biogás, Potencial Energéticos, análise de pré-viabilidade.

1. Introduction

Biomass is a renewable resource that can promote sustainability by appropriate technology use and the management of natural resources. In Brazil there is a great potential for this. Brazil has a high rate of biomass production, and waste production of agro-industrial and zootechnical activities (COLDEBELLA, 2006). The use of renewable biomass for energy generation includes biofuels and bioenergy. The first obtained the appropriate agricultural residues and the second the use of organic waste (LINDEMEYER, 2008).

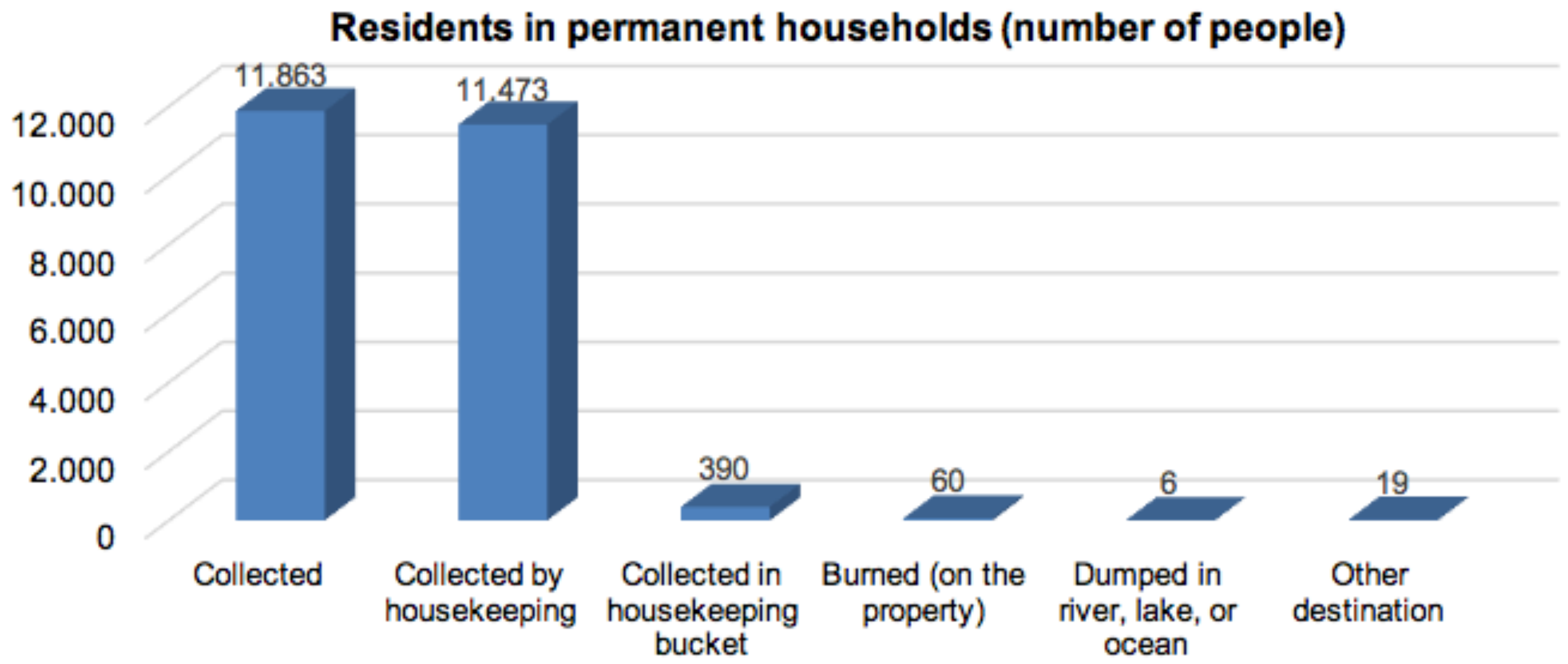
All biodegradable substrates by biological effect are considered biomass (SGANZERLA, 1983). Biomass is the total mass of organic matter that accumulates in a living space. Following this proposition biomass can be classified as all plants and animals, their waste and processed organic substrates (SOUZA; PEREIRA; PAVAN, 2004).

2. Energy potential survey

2.1 Organic Municipal Solid Waste

The region defined for this research was the Agronomy district of the city of Porto Alegre from IBGE demographic data. The Graph 1 shows the basic data for this study.

Graph 1 - Permanent private housing units Agronomy district for destiny of MSW.



Note: Adapted from IBGE (2010).

Based on information from Graphic 1 and DMLU (2013) it was possible to estimate the daily amount waste production. It was considered the total population of the district of 11,948 inhabitants, the share of 43.8% and 57.3% organic biodegradable waste present in the waste generation rate of 0.72 kg and 0.76 kg per person per day. The values correspond to the years 2002 and 2010 respectively. In Table 1 are presented two residues generation values in tons per day.

Table 1 - Value basis for the calculation of the rate of daily waste generation.

Year	Waste generation rate (kg per person per day)	Organic portion (%)	Estimated organic waste generation (kg per day)
2002	0.72	48.80	3767
2010	0.76	57.50	5203

Note: Adapted from IBGE (2010) and DMLU (2013).

There were selected two per capita rate values of household waste generation. To determine a secure range of total organic matter, because of to the variation of these amounts.

2.2 Agricultural Waste

According to the IBGE information, the annual municipal agricultural production was verified. In Tables 2 and 3 are the productions from the temporary municipality farming and microregion of Porto Alegre in the 2000-2013 period.

Table 2 - Agricultural production data from the microregion of Porto Alegre.

Microregion of Porto Alegre							
Yield (tons per year)							
Cultures	2000	2001	2002	2003	2004	2005	2006
Rice	160,072	130,241	157,849	166,448	203,998	215,473	246,889
Sweet Potatoes	19,045	21,035	21,005	21,586	19,678	16,683	18,183
Potatoes	1,881	2,047	1,972	1,987	2,078	1,843	1,542
Sugar Can	15,882	18,728	25,104	25,706	23,492	17,713	27,803
Onion	444	398	414	413	419	398	445
Beans	682	709	671	595	754	714	669
Tobbaco	3,540	3,540	4,095	5,940	8,745	6,067	8,485
Manioc	39,418	39,868	47,459	46,703	43,512	38,952	41,742
Watermelon	1,138	9,132	9,436	7,772	7,807	7,014	5,723
Melon	1,367	1,413	2,565	2,836	2,055	1,966	1,975
Corn	8,200	9,032	8,479	11,583	7,851	3,181	8,939
Soy	165	165	573	618	409	627	2,276
Tomato	1,388	907	1,152	1,220	1,220	1,170	1,260
-	2007	2008	2009	2010	2011	2012	2013
Rice	269,072	267,077	314,787	294,250	324.,549	345,963	364,123
Sweet Potatoes	18,933	19,226	19,275	15,510	21,166	24,950	24,919
Potatoes	1,600	1,735	1,584	1,656	1,743	1,340	1,362

Sugar Can	28,082	29,564	28,934	29,734	30,568	31,226	35,521
Onion	453	444	413	423	476	505	603
Beans	810	790	760	731	944	620	758
-	2007	2008	2009	2010	2011	2012	2013
Tobbaco	8,266	8,865	9,067	7,016	8,562	7,902	7.902
Manioc	43,936	41,381	40,133	39,219	41,344	39,320	40,413
Watermelon	19,256	14,631	11.377	10,470	25,973	13,235	14,647
Melon	4,185	4,189	3,163	4,344	5,308	5,230	3,715
Corn	11,498	10,789	10,119	11,730	13.145	8,153	13,047
Soy	380	397	377	1,493	1,560	2,696	4,879
Tomato	1,219	1,264	1,116	1,007	1,494	1,373	1,489

Note: Adapted from IBGE (2013).

Table 3 - Agricultural production data in the city of Porto Alegre.

Porto Alegre							
Yield (tons per year)							
Cultures	2000	2001	2002	2003	2004	2005	2006
Rice	4,752	4,752	4,752	5,400	2,500	3,000	2,592
Sweet Potatoes	82	82	200	300	300	300	300
Potatoes	18	18	9	-	-	-	-
Sugar Can	-	588	588	840	840	630	630
Onion	64	18	18	18	18	18	18
Beans	7	7	5	7	7	8	4
Manioc	400	400	400	400	500	350	350
Watermelon	117	35	14	14	14	14	14

Melon	162	135	225	375	375	375	375
Corn	140	140	140	140	120	-	120
Tomato	80	120	300	300	300	320	320
-	2007	2008	2009	2010	2011	2012	2013
Rice	2,517	3,050	3,050	2,750	1,775	1,811	1,925
Sweet Potatoes	300	300	300	300	300	300	300
Sugar Can	630	630	450	630	630	630	630
Onion	18	9	9	9	9	9	6
Beans	5	5	4	5	3	2	2
Tobbaco	-	5	-	-	-	-	-
-	2007	2008	2009	2010	2011	2012	2013
Manioc	350	350	350	350	350	500	500
Watermelon	14	-	-	-	-	-	-
Melon	375	375	500	1500	1500	900	900
Corn	125	125	125	125	125	100	90
Tomato	320	320	320	240	320	320	320

Note: Adapted from IBGE (2013).

Tables 2 and 3 show the amount of cultures produced per year. The information shows the variability of some cultures. These cultures were excluded due to low reliability in the generated values. In addition, it was considered the crops with the largest production and information available to their energy use. Therefore they were discarded all not listed in Tables 4 and 5.

Table 4 - Agricultural production data of selected cultures of microregion of Porto Alegre.

Microregion of Porto Alegre							
Yield (tons per year)							
Cultures	2000	2001	2002	2003	2004	2005	2006
Rice	160,072	130,241	157,849	166,448	203,998	215,473	246,889

Beans	682	709	671	595	754	714	669
Manioc	39,418	39,868	47,459	46,703	43,512	38,952	41,742
Corn	8,200	9,032	8,479	11,583	7,851	3,181	8,939
Soy	165	165	573	618	409	627	2,276
-	2007	2008	2009	2010	2011	2012	2013
Rice	269,072	267,077	314,787	294,250	324,549	345,963	364,123
Onion	453	444	413	423	476	505	603
Beans	810	790	760	731	944	620	758
Manioc	43,936	41,381	40,133	39,219	41,344	39,320	40,413
Corn	11,498	10,789	10,119	11,730	13,145	8,153	13,047
Soy	380	397	377	1,493	1,560	2,696	4,879

Note: Adapted from IBGE (2013).

Table 5 - Agricultural production data of selected cultures in the municipality of Porto Alegre.

Porto Alegre							
Yield (tons per year)							
Cultures	2000	2001	2002	2003	2004	2005	2006
Rice	4,752	4,752	4,752	5,400	2,500	3,000	2,592
Beans	7	7	5	7	7	8	4
Manioc	400	400	400	400	500	350	350
Corn	140	140	140	140	120	-	120
Soy	-	-	-	-	-	-	-
-	2007	2008	2009	2010	2011	2012	2013
Rice	2,517	3,050	3,050	2,750	1,775	1,811	1,925
Beans	5	5	4	5	3	2	2
Manioc	350	350	350	350	350	500	500

Corn	125	125	125	125	125	100	90
Soy	-	-	-	-	-	-	-

Note: Adapted from IBGE (2013).

After the selection of potential cultivations were analyzed their behavior through data variability from one year to the next, which demand considerations before calculations.

For this study were considered distinct data ranges for waste production potential calculation.

Because of to the impossibility to perform a reliable future projection of agricultural production, a task that demands a great amount of technical information and analysis were obtained through Geographic Information Systems (SIG) and Remote Sensing (RS). The land use in subsequent years were set in the historical data obtained in the research.

Only two were kept quantity values of different years for each culture, to a maximum estimate and other minimum annual agricultural production. This last consideration was made due to the impossibility of predicting the dynamics of land use.

Without a dedicated study beyond the statistical data obtained, it is doubtful make conclusions only by the amount of data output for a long period of time. By own data this factor demonstrates evidence, analyzing soybean production in the microregion between 2009 and 2010, there is a considerable production increase. Increased use of land for this crop, which prevents the historical data prior to 2009 for the analysis of the current reality.

Were selected the data from the last five years, as these probably reflect how it is being carried out land use until recently. There was exception for soybean cultivation, which was selected the last four years we have adopted the maximum and minimum value for a security strip production municipal annual agricultural residue and micro. The following Tables 6 and 7 show the values selected for calculation waste.

Table 6 - Minimum and maximum values selected for the waste generation to the microregion.

Microregion of Porto Alegre		
Yield (tons per year)		
Cultures	Minimum	Maximum
Rice	294,250	364,123
Beans	620	944
Manioc	39,219	41,344
Corn	8,153	13,145
Soy	1,493	4,879

Note: Adapted from IBGE (2013).

Table 7 - Minimum and maximum values selected for the waste generation for Porto Alegre.

Porto Alegre

Yield (tons per year)		
Cultures	Minimum	Maximum
Rice	1,775	3,050
Beans	2	5
Manioc	350	500
Corn	90	125
Soy	-	-

Note: Adapted from IBGE (2013).

With the data of the total production may be estimated upper and lower amount of agricultural waste. Next follows the tables 8 and 9 containing the results of waste amount of simulations obtained from the municipality and the selected microregion.

Table 8 - Minimum and maximum values estimated waste generation to the microregion.

Microregion of Porto Alegre		
Yield (tons per year)		
Cultures	Minimum	Maximum
Rice	182,435	225,756
Beans	288	438
Manioc	10,197	10,749
Corn	5,479	8,833
Soy	1,030	3,367

Note: IBGE (2013).

Table 9 - Minimum and maximum values estimated waste generation to the microregion.

Porto Alegre		
Yield (tons per year)		
Cultures	Minimum	Maximum
Rice	1101	1891

Beans	1	2
Manioc	91	130
Corn	60	84
Soy	-	-

Note: IBGE (2013).

The Biogas Plant converts agricultural waste into biogas and were considered some caveats before the effective planning, as not all cultures have the basic information for the specific production of biogas. As for the other remaining crops have as waste only straw vegetables from the harvest, then were considered for the plant supply the corn stover, soy, beans and rice.

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3. Planning biogas plant

Based on the potential of survey research it was possible to determine the amount of waste from sources analyzed in the previous sections. From they were made of logistics cost residue analysis, biogas production estimates, electricity and bio-fertilizer, and possible revenues from them. Thus it is possible to determine an economic pre-feasibility.

3.1 Organic Waste collected from the Agronomy district

The first step to be considered in the planning of Organic Solid Waste was the transportation logistics for the handling of the source substrate to the plant, for it has consulted the historical database of the National Sanitation Information System that contains data based on various sanitation indicators of all municipalities in Brazil.

These is a database administered at the federal level linked to the ministry of cities, which contains institutional character information, administrative, operational, managerial, economic, financial and quality of the provision of water services, sewage and management solid waste (SNIS, 2015). One indicator of this database is the unit cost of collection service in R$ per ton, which is calculated by the total expense of the city with the collection service divided by the total amount of waste collected (SNIS, 2013). To Porto Alegre this indicator had a score of 89.55 R$ per ton, which corresponds to the operating context of the year 2013, given the latest available on the system.

The choice of cost is justified in the joint operation of the event with the city, because it has exclusive competence in the collection, transportation and disposal of Solid Waste in accordance with Article 10 of the Municipal Urban Cleaning Code (PORTO ALEGRE, 2014). It was considered for this paper the regular collection system of Solid Waste, so the cost value corresponds to the current infrastructure operation by the municipality.

For this paper was calculated the cost of obtaining a substrate for a complete year, resulting in R$ 123,157.33, based on the lower limit of organic MSW generation.

The dimensioning of the Biogas Plant was based on the total residue data generation, in which case we used the lower limit value of 3767 kg per day. For Organic Waste parameters were organized according to the table 10.

Table 10 – Parameters of Organic Waste for planning the Biogas Plant.

Amount of waste in the year	1,375,291 kg per year

Especific mass	900 kg per m³
Dilution	25%

Note: Adapted from Lima *et al.,* (2010).

The dilution level used corresponds to the study of *Lima et al.,* (2010), which demonstrates a better production of biogas for such dilution fraction compared to 0% of the same. With this information can be estimated the production of biogas. Based on Reichert (2005) was adopted a rate of 120 m³ per ton for biogas generation with the organic part. Thereby, the estimated amount of biogas is 165,034 m3 per year.

3.2 Agricultural Waste for Microregion and Municipality

For agricultural waste is fundamental analysis of the cost of transport as mentioned in the argument to define the maximum area as the microregion of Porto Alegre. Oliveira (2011) shows a method for determining biomass transportation costs. The table uses the cost method values based on the data from Sifreca (2015). It shows the road transport cost of agricultural production. Values were found for soybeans and corn, 0.40 and 0.60 R$ per ton for each km and the intermediate value of 0.50 R$ per ton for each km was used of other cultures that are not such data available. With this information, it is possible to estimate the logistical cost of waste to the different cultures chosen. For the microregion was chosen two one as maximum reference distances characterized by the distance from the plant site to the far boundary of the area in the 95.70 km in the case of campus to the city of Sertão Santana, and an average between municipalities that makes up the micro and the installation location corresponding to 50.16 km.

In case the municipality was used an average distance of 19 km from implementing local to the access between the BR-116 and BR-290 (20.8 km), and the far south (17.2 km). In the colon focuses much of the production of temporary crops, which are analyzed in this work. Figure 3 explains the choice of the selected distances because the temporary cultivation of legend, distinguished by color locations which presents cultures.

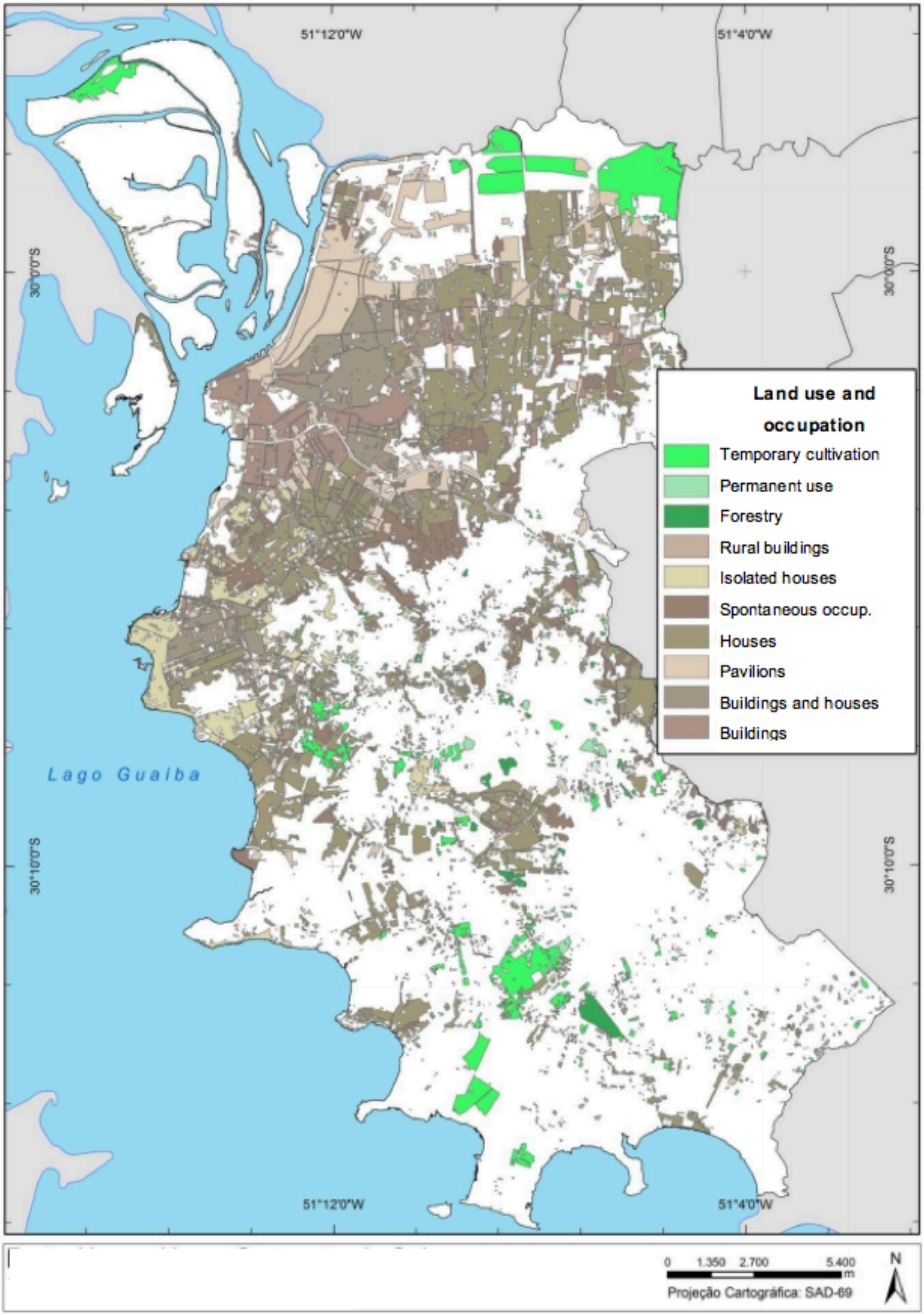

Figure 3 - Use and occupation of Land in the city of Porto Alegre.
Note: Kozenieski (2010).

With the previous settings and amount of certain waste values of potential survey, calculate the estimates of the logistics cost for each crop. Table 11 shows the results of the costs per ton, from the previously set distance, and estimates for disposal of all waste estimated for the microregion.

Table 11 - Estimated cost to transport biomass to the Biogas Plant.

Cultures	Costs (R$ per tons for each km)	Distance (km)		Costs per tons (R$/ton)		Costs per year for transportation (R$)	
	-	Average	Maximum	Average	Maximum	Average	Maximum
Rice	0.50	50.16	95.70	25.08	47.85	4,575,470	8,729,515
Bean						7,223	13,780
Corn						137,413	262,170
Soy						25,832	49,285

In Table 12, there are the calculated values for the municipality of Porto Alegre.

Table 12 - Estimated cost to transport biomass to the Biogas Plant.

Cultures	Costs (R$ per tons for each km)	Distance (km)	Costs per tons (R$/ton)	Costs per year for transportation (R$)
Rice	0.50	19	9.5	10,454
Bean				9.5
Corn				570
Soy				-

After the survey of the biomass transport costs the plan to estimate biogas production and electricity was made. Based on the reference was obtained from waste into biogas conversion information based on the adopted technology, except bean straw and soy, which was used a straw index of a separate reference. Table 13, following, estimated biogas production considering the minimum estimated value of waste production, the conversion factors of literature and electricity production extrapolation to the city and microregion.

Table 13 - Estimated biogas and electricity for the city of Porto Alegre.

Cultures	Conversion factor (Nm³/t)	Municipality - Biogas and electricity production		Microregion - Biogas and electricity production	
		Biogas (m^3)	kWh	Biogas (m^3)	kWh
Rice	190	209,095	462,100	34,662,650	76,604,456
Bean	240	240	492	69,120	152,585
Corn	200	12,000	26,732	1,095,800	2,421,636
Soy	240	-	-	247,200	546,402

Note: Information from Friehe; Weiland; Schattaauer (2010), The National Non-Food Crops Centre (2015) e Farret (1999) apud Lindemeyer (2008).

Similarly to the previous section was made to estimate energy offset credits produced by the biogas conversion connected to the electricity distribution network. So the Table 14 with the credit amounts in R$ for energy from agricultural waste based on the defined rate of 0.36 per kWh.

Table 14 - Amounts of energy offset credits injected into the utility distribution network.

Cultures	Tariff value (R$/kWh)	Municipality - Compensation credits (R$/year)	Microrregion - Compensation credits (R$/year)
Rice	0.36	166,356	27,577,604
Bean		177	54,930
Corn		9,623	871,789
Soy		-	196,704

Table 15 shows the biofertilizer production estimate considering 80% of waste generation and commercialization cost of R$ 30 per ton, according to the discussion held in the end of the previous section.

Table 15 - Biofertilizers production estimate and income for the municipality.

Cultures	Biofertilizer the trading price (R$ per ton)	Municipality - production and income of Biofertilizer		Microregion - production and income of Biofertilizer	
		Tons	R$	Tons	R$
Rice	30	880	26,412	145,948	4,378,440

Bean		0.74	22	230	6,904
Cultures	Biofertilizer the trading price (R$ per tons)	Municipality - production and income of Biofertilizer		Microregion - production and income of Biofertilizer	
-	-	Tons	R$	Tons	R$
Corn	30	48	1,451	4,383	131,491
Soy		-	-	824	24,724

Note: Oliveira (2009) e Santos (2009).

From the amounts of revenues with biofertilizers and energy and disposal costs of waste collected, it was estimated that the balance is present in the following table for the crops considered.

Table 16 - Estimated gain based on collected revenues and costs.

Cultures	Municipality - Gain (R$)	Microregion - Gain (R$)	
-	-	Average costs for transport (R$)	Maximum costs for transport (R$)
Rice	182,314	27,380,574	23,226,529
Bean	190	54,611	48,054
Corn	10,504	865,867	741,110
Soy	-	195,596	172,143

The gain values in both cases show that the transport is not an absolute restriction economic factor.

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4. Conclusions

The estimation of agricultural waste and urban domestic showed quantitative values to be used in the Biogas Plant. It was selected as the boundary region above the microregion of Porto Alegre, which showed a large amount of waste available for power generation. It was selected as substrate, rice, beans, corn and soybeans, which generated at the lower limit adopted 182,435 tons per year, 288 tons per year, 5,479 tons per year and 1,030 tons per year respectively. For the city, was obtained for rice 1,101 t per year, beans 1 ton per year and corn, 60 tons per year of waste. For the survey of organic household waste at the Agronomy neighborhood was established a minimum rate of generation of 3,767 kg per day of waste. It was based on official data from the municipality and the IBGE. In all three cases the waste production estimates defined minimum and maximum values, so as to give a range of values.

This was done as an alternative to a future projection, which was not performed by the complexity of the variables that make up the dynamics of agricultural production and organic waste. For the survey of organic household waste Agronomy neighborhood was established a minimum rate of generation of 3,767 kg per day of waste. It was based on official data from the municipality and the IBGE. In all three cases the waste production estimates defined minimum and maximum values, so as to give a range of values. This was done as an alternative to a future projection, which was not performed by the complexity of the variables that make up the dynamics of agricultural production and organic waste. With the determination of such range can be observed that the possibility of future generation of waste falls within this range. Cultures and types of waste is concluded that the greatest potential substrate value found were the rice residues. The amount of agricultural production in the microregion is more significant in relation to the others considered. Quantitative planning results were divided into determining logistic cost of waste and estimate of biogas, electricity and bio-fertilizer. Also the amounts of waste were collected and their revenues. This was based on a methodology that was selected microregion of Porto Alegre with a maximum distance of the city to the plant and an average of all. Certain costs of transport to the disposal of all biomass was done in order to compare with the total revenues from the clearing of electricity and sale of biofertilizers. In the case of a scaled plan is required a specific analysis of that cost, because not all waste will be necessary for the plant and its distribution in the microregion municipalities is irregular. This makes it essential analysis dedicated the amount of waste for each municipality to internal microregion, according to the substrate requirements of the Biogas Plant. For the city of Porto Alegre the total cost of disposal of waste with more significant amounts.

Biogas production estimates of agricultural waste are 34,662,650 m^3, 69,120 m^3 1,095,800 m^3 and 247,200 m^3 for rice, beans, corn and soybeans, respectively. The conversion was estimated for electrical energy and the amount of biofertilizer generated. It was determined that the transport has absolutely restrictive character. The estimates of costs and revenues, and the result of the gain calculation is economically viable for both the setting of the microregion and to the city. Thus opens the possibility to continue with the project's design activities and a full feasibility analysis of an Industrial Plant.

In the case of organic waste was directly raised the cost per ton based on information about the municipal collection service.

The estimated amount of organic waste is a biogas production volume of 165,034 m^3 annually, which can be converted into 364,727 kWh of electricity. The bio-fertilizer production estimate was 1,100,232 kg per year. The scenario achieves the economic pre-feasibility for the method used in this paper.

For the injection of the electricity generated in the distribution grid requires more specific analysis of the project. Depending on conversion and its scale power generation technology, there may be incompatible situations for a connection to the electricity distribution grid.

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