A Sustainable Rural Electrification of Morocco using Stevia Biomass Power Generation: Lessons for Paraguay

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***Abstract*—There is an overreliance of the energy sector of many developed and developing countries on fossil fuels to satisfy their growing energy needs. Paraguay and Morocco are noted to derive the greater share of their energy from fossil fuel imports. However, the high import bills and carbon emissions, as well as the depleting nature of fossil resources have compelled these countries to seek sustainable power sources. Bioenergy from agricultural residues is an example of such sources due to the high agricultural production in Paraguay and Morocco. Therefore, in this study, the potential of electric energy generation from the biomass of three different varieties of Bertoni namely; Gawi, SugHigh3, and Pop in rural regions of Morocco has been analyzed. The analysis showed that the capacity of the electricity generation from stevia biomass for the different regions considered in the study ranged from 421.2 to 16865 W/ha, while the leaf yield and HHV variation for the different varieties ranged between 2.15 t/ha and 7.86 t/ha, and 21.24 MJ/kg and 27.83 MJ/kg, respectively. By considering a 1.66-kW biogas generator with operating hours of 8761 per year and LHV of 26.436 MJ/kg, as well as gasification ratio of 0.7 and 63.1% carbon content for HOMER simulation, a total capacity of 6.64 MW is suggested for installation in Tazuta. The findings indicate that Bertoni's dry leaves are excellent biomass resources for energy production in rural regions of Berkane, Larache, Marrakech, Rabat, and Sefrou and they can give us good lessons for rural electrification of Paraguay.**

Link to graphical and video abstracts, and to code: https://latamt.ieeer9.org/index.php/transactions/article/view/9123

***Index Terms*—Crop biomass, Rural electrification, Stevia residues, Electric power yield.**

I. INTRODUCTION

Paraguay and Morocco rely on import of energy, specifically fossil fuels in order to satisfy a major portion of their upscaling main power requirement [1]. Currently, fossil fuels such as coal, oil, and natural gas are estimated to supply majority of these nations' whole main energy requirements [2]. Due to the accompanying negative effects of fossil consumption, including the expensive energy import bills, price fluctuation, high carbon emissions, and the depletion of fossil reserves, there is a need for these countries to urgently increase their sustainable energy utilization by shifting from fossil-based to renewable-based energy generation to align with international protocols like the Paris Agreement [3], [4].

Due to the surge in electricity demand [5], and the need to provide energy services that can satisfy this demand, as well as the rapid acceleration in rural electrification [6] to align with the sustainable development goal seven (SDG-7) of the United Nations, the deployment of distributed renewable electricity generation [7] in the Paraguayan and Moroccan energy sectors should be overemphasized. For example, in Morocco, the share of renewable energies in the country's power supply mix has seen a marginal upward adjustment from 28% in 2000 to 37% in 2018 and is projected to reach 52% by 2030 [8]. Considering the high rate of biomass generation globally, biomass power generation can serve as a major push in the Paraguayan and Moroccan energy industries in reaching the target by 2030 [9].

Biomass is produced from varied sources including agriculture, industries, and domestic activities, making it the 4th most significant source of energy, coming behind natural gas, coal, and oil globally [10]. Biomass power generation is noted to be one of the cleanest energy sources for clean power production, and therefore can help to mitigate some of the challenges that come with fossil based power generation like high carbon emission, price volatility, and the high power transport cost due to the centralization of fossil based power which are usually grid connected making their connection to rural areas costly and uneconomic [11]. Biomass can be used to generate localized power and heat via combustion or may be utilized to create intermediate fuels through gasification, anaerobic digestion, and fermentation which can be injected into a gas engine for electricity generation.

The potential of electricity generation from animal wastes for meeting the electric power demand of rural areas has been investigated in [12]. The results showed a good potential in cow manure for electricity generation in villages. However, this kind of energy resource could not satisfy the whole electrical demand of the studied area without the contribution of wind and solar energy due to the limited access to water resources which are required for anaerobic digesters. To resolve this problem, study [13] suggested gasification technology for generating electricity rather than anaerobic digestion. Also, [14] studied the potential of using sheep manure to increase biomass capability in meeting the load

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demand of the same areas studied in [12]. Nevertheless, the biogas power from sheep manure could not also satisfy the whole electric consumption without the aid of wind and solar power generation.

Also, in [15], small-scale hybrid biomass and solar power plants were used to provide the heat requirements for rural bathrooms. However, the type of biomass used in the boiler was not mentioned by [15].

Furthermore, in [16], the biogas obtained from landfilled household wastes was utilized to produce energy for urban areas. Although the results from the analysis in [16] indicated that household wastes with 65 to 75% organic matter are important resources for electricity generation in urban areas, they are not available for rural electrification.

For this reason, in [17], the potential of olive agricultural residues was studied for supplying the whole electricity demand of rural areas using combustion. The results indicated that power generation from agricultural wastes is not able to supply the electric energy required by all consumers in rural regions, but it is a promising way to produce clean electricity.

Even though studies conducted on rural electrification indicate a good potential for energy production from biomass, especially agricultural residues [1], these biomass sources cannot meet the entire energy demand of the respective study locations. Therefore, investigating the potential of new biomass energy resources is necessary for upscaling the Paraguayan and Moroccan renewable energy shares in their energy matrixes. In [18], argane fruit was suggested as a new raw material for bioethanol production. However, argane can be planted only in coastal and semi-continental districts.

Bertoni (Stevia) (observe Fig. 1 [19]) is a very important medicinal plant for the treatment of skin abrasions, blood pressure, cardiovascular disease, cancer, obesity, and diabetes. It is also used as a sweetener with fewer harmful effects within the food sector, where significant health issues have arisen from high usage of sugar in recent times [20]-[22].

Additionally, the leaves of the plant (refer to Fig. 2) contain high energy content which can be utilized for power production [23], [24]. The enormous benefits derivable from the crop have resulted in an increased interest in Bertoni cultivation in countries like the USA, France, Canada, and Germany [25], [26]. For these reasons, the study [27] evaluated the possibility of electric power generation from Bertoni in different climatic conditions of Morocco and estimated the potential of obtainable biomass from this new crop all over the country. Even though the results of the study indicated the whole Moroccan territory is potent for Bertoni cultivation, nevertheless the attainable energy amount of this crop was not calculated. Consequently, the potential of energy generation from dry leaves of Bertoni was calculated in [28] without studying the plant's biomass capability in supplying the whole electricity demand of under-studied regions. Additionally, the study [28] performed a limited analysis of power generation of the residues. Therefore, the present paper estimates the potential of electric energy generation from dry leaves of Bertoni and the capability of supplying the whole electricity demand in selected regions. In addition, the current research investigates the capability of load satisfaction by the plant's dry leaves in rural areas of Sefrou province through HOMER simulation.

Research on triple different types of Bertoni has been conducted in six distinct zones to demonstrate the potential contribution of the crop in electric energy generation, making it the first time that the potential of bioelectricity from Bertoni is measured in different geographical locations, climatic conditions, and geological regions. The possibility of satisfying the whole electricity demand in one selected area has been modeled in HOMER software. All electric calculations can be extended to the other study areas of this paper and rural areas of Paraguay after estimating the electricity consumption of the location.

a) Herbaceous shrub

b) Flowers

Fig.1. Stevia rebaudiana plant [19].

a) Fresh leaves

b) Dried leaves

Fig.2. Leaves of Bertoni [19].

II. Electricity Generation from Berton's Dry Leaves

Annual energy obtained from Bertoni's dry leaves per unit hectare (Q_i) of Bertoni cultivation can be calculated using the following equation [28].

$$Q_i = 1000 \times H_i \times n_i \times HHV_i \times \beta \quad (1)$$

In equation (1), H_i is the ratio between leaf yield and plant yield known as harvest index, n_i (t/ha) is the annual dry leaves yield, and HHV_i (kJ/kg) refers to the higher value of heating (HHV) for i-th variety of Bertoni. The HHV may be estimated through relation (2) based on dry leaves' nitrogen, hydrogen, and carbon compositions [29]. Moreover, β represents the combustor's efficiency employed for generating heat energy in a power plant.

$$HHV_i = 3.55C_i^2 - 232C_i - 2230H_i + 51.2C_iH_i + 131N_i + 20600 \quad (2)$$

In equation (2), N_i, H_i, and C_i respectively are the percentage weight of nitrogen, hydrogen, and carbon with respect to dry leaves of i-th variety of Bertoni. The lower value of heating (LHV) has been accounted for through equation (3) adopted from the study [30].

$$LHV_i = HHV_i\left(1 - M\right) - 2.443M \quad (3)$$

In equation (3), M denotes the content of moisture in a particular residue of Bertoni crop which is able to be estimated using equation (4).

$$M = \frac{W_w - W_d}{W_d} \quad (4)$$

Where W_w is the weight of the Bertoni crop residues before drying and W_d is the weight after drying in an oven.

Fig. 3 gives the model for a power plant generating electricity using steam. From this model, yearly electrical power that can be generated from the burning of dried Bertoni leaves is computed via the use of equation (5).

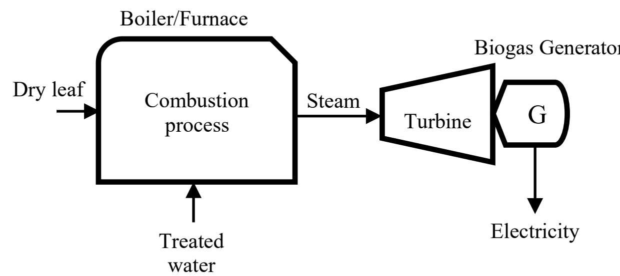

Fig. 3. Electric power station fueled by Stevia biomass.

$$E_i = \frac{TQ_i\eta}{8761 \times 3600} \quad (5)$$

Where E_i is the electricity that can be obtained from Bertoni variety i (kWh), T is the whole annual operation hours of the biomass power plant, and η is the efficiency of the Rankine cycle, which is a variable that is considered to be between 25% and 40% ($0.25 \leq \eta \leq 0.40$) [31].

Subsequently, the electricity generation capacity of each variety of Bertoni (P_i) from the steam power plant can be calculated using equation (6).

$$P_i = \frac{E_i}{8761 \times Cf} \quad (6)$$

Where Cf indicates the factor of power station capacity which is taken between 0.7 and 0.9. This indicates that the power station does not operate at its maximal capacity of generation; instead, 10 to 30% of its output is kept for critical moments.

III. Results and Analysis

Three different varieties of Bertoni crops, which are the Pop INRA, Sug-High3, and Gawi, have been opted for the case study under different weather conditions, where the influence of weather on the crop yield and energy production was examined. The selected varieties are known to be the most popular varieties of bertoni but respond differently to different climatic conditions. The selected Stevia types have been seeded under a glasshouse condition at six various districts in Morocco, which are; Sefrou, Rabat, Marrakech, Larache, Berkane, and Agadir according to Fig. 4 [32]. These districts are noted to have a low rural electricity access rate hence will be favorable for local biomass power generation.

With an average plantation spacing of 30 cm in each row and half a meter between two beside rows, it is estimated that about 65000 numbers of Bertoni can be planted in a hectare. Table I gives the yield of dried leaves, the content of moisture, the average volumes of hydrogen, carbon, and nitrogen for diverse Bertoni species, using data presented by [24], [27], and [33]. The dry leaf yield depends on the productivity of bertoni at a particular location, which is affected by the climate and soil nutrient levels of the particular location.

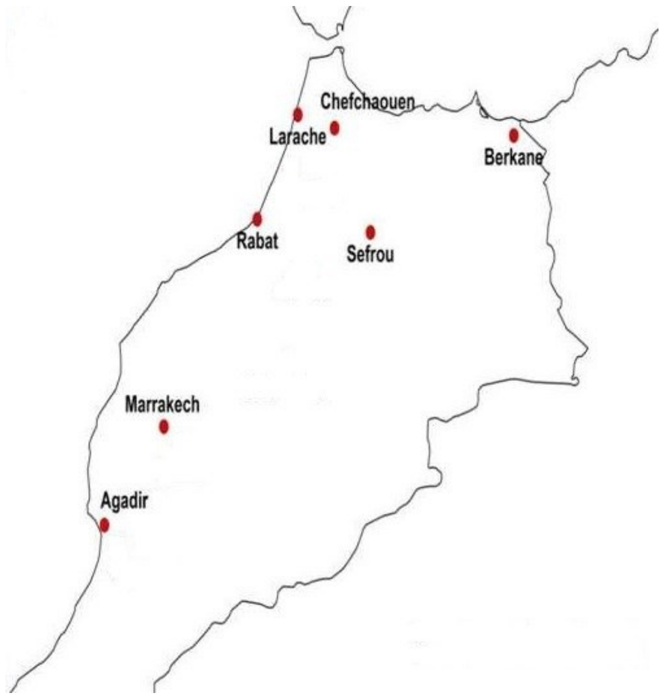

Fig. 4. Potential studied regions for Bertoni cultivation in Morocco [32].

TABLE I
YIELD OF LEAVES AND CHARACTERISTICS OF VARIED BERTONIS IN SIX REGIONS

Region	Variety	Yield (t/ha)	Nitrogen (wt%)	Carbon (wt%)	Hydrogen (wt%)	Moisture (wt%)
Agadir	Gawi	2.15	0.06	52	7.16	-
	SugHigh3	3.73				-
	Pop INRA	4.63				8.31
Berkane	Gawi	5.98	0.05	61.90	7.24	-
	SugHigh3	4.26				-
	Pop INRA	6.68				5.95
Larache	Gawi	6.30	0.06	56	7.75	-
	SugHigh3	6.80				-
	Pop INRA	7.86				7.04
Marrakech	Gawi	6.33	0.06	52.30	7.30	-
	SugHigh3	6.71				-
	Pop INRA	7.33				4.97
Rabat	Gawi	4.39	0.04	52	7.45	-
	SugHigh3	5.12				-
	Pop INRA	7.42				8.24
Sefrou	Gawi	6.57	0.22	63.10	7.70	-
	SugHigh3	4.31				-
	Pop INRA	6.49				5.01

A. Estimation of Heat Energy and Electricity Generation Potential

According to the data presented in Table I, the HHV, LHV, and the energy that can be obtained from Bertoni varieties in the several districts are computed using relations (1) to (3) and illustrated by Table II.

TABLE II
LHV, HHV, AND ENERGY YIELD OF VARIED BERTONIS IN DISTINCT AREAS

Region	Variety	HHV (kJ/kg)	LHV (kJ/kg)	Energy yield (kJ/ha)
Agadir	Gawi	21239	-	36531080
	SugHigh3		-	63377176
	Pop INRA		19474	78669256
Berkane	Gawi	26648	-	127484032
	SugHigh3		-	90816384
	Pop INRA		25062	142406912
Larache	Gawi	23687	-	119382480
	SugHigh3		-	128857280
	Pop INRA		22019	148943856
Marrakech	Gawi	21453	-	108637992
	SugHigh3		-	115159704
	Pop INRA		20387	125800392
Rabat	Gawi	21362	-	75023344
	SugHigh3		-	87498752
	Pop INRA		19602	126804832
Sefrou	Gawi	27830	-	146274480
	SugHigh3		-	95957840
	Pop INRA		26436	144493360

With a harvest index of 1 for all crops [30], annual operation hours of 8761, η=30%, and β=80% as used in the study [31], and data presented in Table II, the electricity generation and the capacity of electric power generation are presented in Table III according to the computation of equations (5) and (6). The factor of 0.825 is setup for capacity of power stations [31] to reserve a 17.5% of generation for crisis moments.

Table I illustrates the highest yield for dried leaf of Pop INRA among others in all regions except Agadir. This variety has an average dry leaf yield ranging from 4.63 t/ha recorded at Agadir to 7.86 t/ha recorded at Larache.

The Gawi variety had dry leaf yield varying between 2.15 and 6.57 t/ha, with the lowest and highest yield being recorded at Agadir and Sefrou respectively, whiles the SugHigh3 variety yielded leaves ranging in interval of 3.73 and 6.8 t/ha, respectively. In terms of SugHigh3, the highest dry leaf yield was recorded at Marrakech and Larache regions, whiles the Gawi recorded its peak dry leaf yield at Marrakech and Sefrou. The Gawi variety recorded the lowest dry leaf yield of 2.15 t/ha in Agadir. Meanwhile, the yearly yield of dried leaves for the same Gawi variety in the country of origin, Paraguay, is about 4.3 t/ha [32]. The yield of dried leaves is variable for USA from 4.12 to 7 t/ha and for France from 1.11 to 4.56 t/ha [34], and is 1.83 t/ha in Switzerland [33]. The difference in leaf yield can be attributed to the difference in climatic conditions and soil for different regions.

TABLE III
ELECTRIC ENERGY AND POWER GENERATION CAPABILITIES FROM BERTONI IN DISTINCT ZONES

Region	Variety	Electric energy (kWh/ha)	Electric power (kW/ha)
Agadir	Gawi	3044	0.4212
	SugHigh3	5281	0.7306
	Pop INRA	6556	0.9071
Berkane	Gawi	10624	1.4699
	SugHigh3	7568	1.0471
	Pop INRA	11867	1.6418
Larache	Gawi	9949	1.3765
	SugHigh3	10738	1.4856
	Pop INRA	12,412	1.7173
Marrakech	Gawi	9053	1.2525
	SugHigh3	9597	1.3278
	Pop INRA	10483	1.4504
Rabat	Gawi	6252	0.8650
	SugHigh3	7292	1.0089
	Pop INRA	10567	1.4620
Sefrou	Gawi	12190	1.6865
	SugHigh3	7996	1.1063
	Pop INRA	12041	1.6659

A significant potential of energy generation from Bertoni's dry leaves is shown by Tables III and II, which can be converted into electricity. Also, a considerable variation in the energy generation potential of the different varieties of Bertoni from one region to another is shown by these tables. The capacity of the electricity generation for the different regions ranging from 421.2 to 16865 W/ha, whiles the leaf yield and HHV varied between 2.15 t/ha and 7.86 t/ha, and 21.24 MJ/kg and 27.83 MJ/kg, respectively. These calorific values are relatively high as compared to other energy crops like sunflower, oil palm, and sugar cane (which are main agricultural products in Brazil and Paraguay) [35]. The electricity generation of a particular crop residue depends on released energy from the crop, which makes crops with higher energy content more feasible for power generation. Hence, to illustrate variability in generation of energy according to area and variety, Fig. 5 compares electric power obtained from different species of Bertoni in various regions.

According to Fig. 5 it can be observed that the Pop INRA has the biggest electric energy yield in comparison with the SugHigh3 and Gawi in the same province, indicating that the best choice for electric power generation is Pop INRA. Sefrou, Larache, and Berkane regions are found to be the most ideal regions for the cultivation of Pop INRA, while Agadir is found to be less favorable for its plantation.

Consequently, it can be said that the climate condition and the variety of the plant affect its energy content, therefore its electricity generation amount.

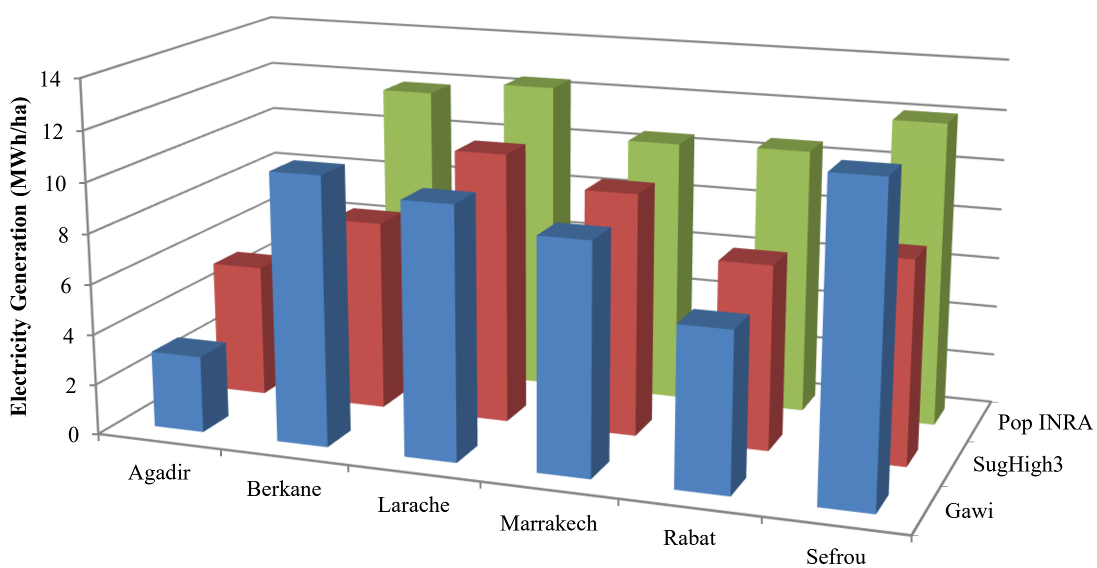

Fig. 5. Electric power generation from Bertoni's biomass.

B. Analysis of Electricity Generation Possibility from Bertoni in Rural Areas of Sefrou Based on Local Electricity Demand

Regarding the availability of electricity demand for some rural areas of Sefrou province such as Tazouta, the capability of Bertoni biomass electricity generation to satisfy the load demand of Tazouta is studied. The total area of the village with 10000 households population situated on a land cover of about 174 km^2 (4.36% of Sefrou area) [13], has about 17000 hectares of arable land [36]. The total electricity consumption of Tazouta is 18 GWh, where its load profile on a summer day with a maximum yearly consumption of 6440 kW at hour 23 is depicted in Fig. 6. Also, the monthly electricity demand of Tazouta in the year was shown in Fig. 7.

From Table III, the Gawi and Pop INRA Bertonis have more electricity generation capability compared to the SugHigh3 variety in Sefrou province and therefore Tazouta. Due to the bigger power generation capability of Pop INRA, Pop INRA was chosen for the case study.

Therefore, the total installable capacity of the biomass power plant can be 1.66 kW per hectare of Bertoni cultivation.

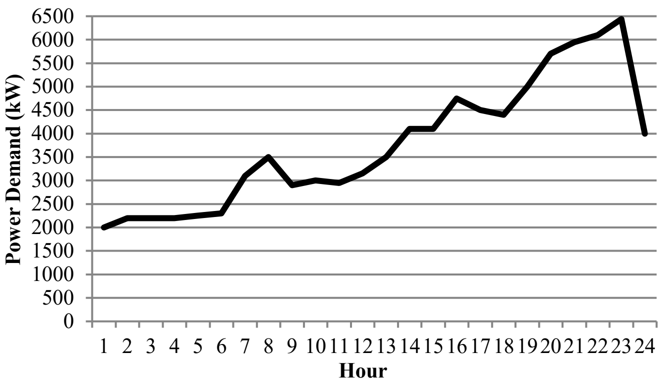

Fig. 6. Load profile of Tazouta in a summer day with peak consumption.

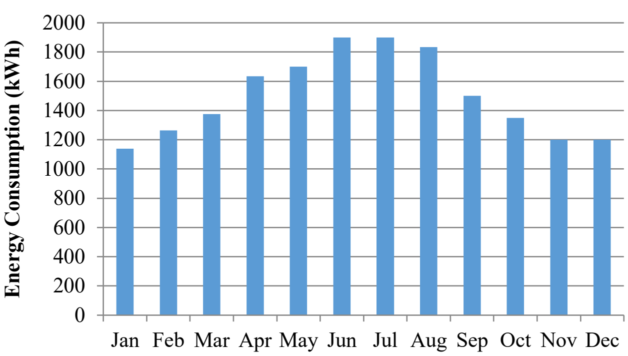

Fig. 7. Monthly electricity consumption of Tazouta during the year.

By considering a 1.66-kW biogas generator with operating hours of 8761 per year and LHV of 26.436 MJ/kg (see the last row of Table II), as well as gasification ratio of 0.7 and 63.1% carbon content for HOMER simulation, a total capacity of 6.64 MW is suggested for installation in Tazuta. This implies that 4000 hectares of arable lands in Tazuta should be allocated to Pop INRA cultivation to satisfy the whole load. This amount is about 23.5% of total agricultural land in the village. Also, the gaseous pollutants emitted by the total biomass installed capacity are listed in Table IV.

Table IV indicates that the amount of carbon dioxide (CO_2) released annually by Bertoni-based biomass power plant is 48.373 t, i.e., 0.83 g/kWh (48373000g/(6640kW×8760h)). This amount is even much lower than cow's manure biomass carbon emission which is mentioned as 50 g/kWh in [13]. The biogas units with a maximum generation capability of 32.95 GWh can have a monthly average generation surplus shown in Fig. 8.

TABLE IV
EMISSIONS OF BIOMASS POWER PLANTS

Pollutant	Emission (kg/year)
Carbon dioxide	48373
Carbon monoxide	137
Unburned hydrocarbons	15.1
Particulate matter	10.3
Sulfur dioxide	0
Nitrogen oxides	1219

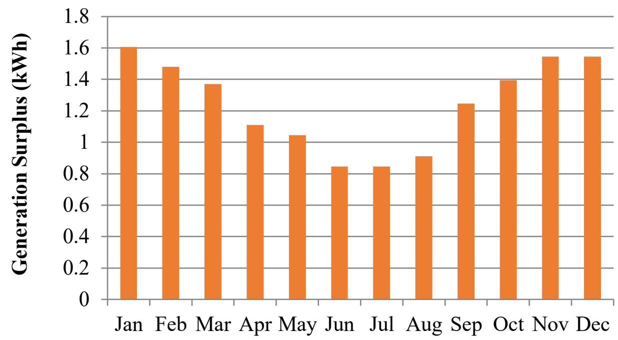

Fig. 8. Monthly average capable generation surplus in Tazouta.

Fig. 8 demonstrates that if the power plant is operated at full load, the surplus electricity can be injected into the national grid or sold in the electricity market with the same investment and operating cost, and biomass fuel requirement because all estimations for power plant capacity were calculated based on the worst scenario (peak load). This fact shows that assigning only 23.5% of arable lands in Tazouta to Bertoni plantation cannot meet the total electricity demand of Tazouta, but can create jobs, connect the rural community to the urban one, and bring about local surplus income generation to the village for improving the local economy. Consequently, cultivating Bertoni crops in rural areas will go a long way to promote rural development and environmental sustainability. The same calculation can be carried out for the other rural areas of Sefrou by using the load pattern of Fig. 6 and knowing the number of households in the rural community. This is because around 80% of electricity is consumed by households in the villages and almost the same sunset and sunrise times and climatic conditions in small provinces such as Sefrou. Sefrou province contains other rural areas listed in Table V in addition to Tazouta. It should be mentioned that the numbers given for households in the table are with respect to Tazouta's households.

The electric load profile of Tazouta was multiplied by the numbers given for households in Table V to achieve the proximate load profile of each rural community. Then, HOMER simulation was conducted for the same biogas generator used in Tazouta village and the results were obtained according to Table VI.

According to Table VI, the minimum cultivation areas and capacities are 2000 ha and 3.32 MW belonging to Tafajight and Azzaba with their populations between 30% and 50% of

Tazouta. Inversely, the maximum arable lands and capacities are 18.26 MW and 11000 ha for rural areas of Ait Sebaa Lajrouf and Aghbalou Aqorar with populations almost three times more than Tazouta. Calculations for other provinces and even rural areas in Paraguay can be done in the same way used for Sefrou. Additionally, the method used in this study can be employed to access the energy generation potential from other crop residues like bagasse from sugar cane, maize residues, rice husk, etc.

TABLE V
NAME AND PERCENTAGE OF HOUSEHOLDS IN RURAL AREAS OF SEFROU COMPARED TO TAZOUTA

Name	Households
Adrej	0.99
Bir Tam Tam	1.66
Dar El Hamra	0.77
Ighzrane	1.88
Mtarnagha	0.89
Oulad Mkoudou	1.39
Ras Tabouda	1.09
Tafajight	0.30
Ain Cheggag	2.49
Ait Sebaa Lajrouf	2.86
Aghbalou Aqorar	2.77
Ahl Sidi Lahcen	0.90
Azzaba	0.47
Kandar Sidi Khiar	1.3
Laanoussar	1.57
Sidi Youssef Ben Ahmed	2.02

TABLE VI
INSTALLED POSSIBLE ELECTRIC CAPACITIES IN EACH RURAL AREAS OF SEFROU AND AREA OF ARABLE LANDS REQUIRED FOR BERTONI CULTIVATION

Name	Capacity (MW)	Cultivation area (ha)	Annual CO_2 emission (t)
Adrej	6.64	4000	48.37
Bir Tam Tam	11.62	7000	80.30
Dar El Hamra	4.98	3000	37.25
Ighzrane	13.28	8000	90.94
Mtarnagha	6.64	4000	48.37
Oulad Mkoudou	9.96	6000	67.24
Ras Tabouda	8.30	5000	52.73
Tafajight	3.32	2000	14.51
Ain Cheggag	16.6	10000	120.45
Ait Sebaa Lajrouf	18.26	11000	138.26
Aghbalou Aqorar	18.26	11000	138.26
Ahl Sidi Lahcen	6.64	4000	48.37
Azzaba	3.32	2000	14.51
Kandar Sidi Khiar	8.30	5000	52.73
Laanoussar	11.62	7000	80.30
Sidi Youssef Ben Ahmed	13.28	8000	90.94

IV. CONCLUSION

There is an enormous potential for Paraguay and Morocco to utilize their renewable energy sources, especially biomass for power generation which can help to curtail the economic and environmental problems that arise from the use of fossil based energy source for power generation including the high energy import bills and carbon emissions. Owing to the large arable lands available in these two countries and the potential to plant different variety of crops which will result in the production of residues that can be used for power generation, it is very essential for these countries to begin to shift attention to bioenergy generation in order to align with international protocols like the Paris agreement and the Nationally Determined Contributions of the country. In this regard, Bertoni, which is a momentous and lucrative replacement for sugar but leads to high yield of dry leaves, is able to be employed for Paraguay's and Morocco's electricity generation sectors, since this plant is highly adaptable to the climatic and agronomic circumstances of Paraguay and Morocco.

Accordingly, the current study has examined the potential of electric power obtained from dried leaves of Bertoni as a novel feedstock in agriculture sector. In the study, the potential of energy production from Bertoni in six suitable areas was assessed. The outcomes of the study indicate that the Pop INRA has the highest energy potential in all regions.

From the results, it was observed that climatic and geographical circumstances impact the amount of energy that can be generated from the dry leaves of Bertoni crop. Also, it was found that Berkane, Sefrou, and Laracheand are most suitable districts for cultivation of Pop INRA, whilst Sefrou and Berkane are proper for Gawi plantation. Furthermore, it was also seen that SugHigh3 Bertoni comes after the Pop INRA species in terms of dry leaf yield and energy generation potential. Additionally, this crop can be seeded in Paraguay and Morocco as a commercial product due to its abundant glycoside content.

Based on electricity generation and demand analysis in rural areas of Sefrou, it was proved that unlike animal and household wastes, the Bertoni crop is able to cover the whole electricity demand of rural areas in Sefrou and even sell its surplus to national grid, including important points for considering in rural electrification of Paraguay.

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