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Technical-economic analysis of alternatives for digestate management and fertilizer production – Brief Report

Climate Helpdesk – Ad hoc support for implementing NDCs, LT LEDS and transparency requirements (MRV systems and M&E adaptation)

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ABOUT THIS DOCUMENT

This brief presents the main results of the technical assistance provided by a team of the Institute of Agrarian Engineering and Soils of the Universidad Austral de Chile to Agrogeneradora, a subsidiary company of Grupo Central Agrícola (Guatemala), as part of the Low Emission Development Strategies Global Partnership (LEDS GP) Climate Helpdesk support.

This technical assistance has been managed by the Secretariat of the Regional Platform for Development and Low Emission Strategies (LEDS LAC), within the framework of the Community of Practice on Bioenergy (Bio-E Cop).

LEDS GP is a global network of governments, organizations and individuals, which was created in 2011 with the aim of facilitating the design and implementation of Low Emission Development Strategies (LEDS) and the establishment of ambitious climate goals. The LEDS GP Secretariat, operated by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), provides access to rapid, high-quality and short-term technical assistance to members of its regional platforms through the Climate Helpdesk.

LEDS LAC is the regional LEDS GP platform for Latin America and the Caribbean. It has more than 2900 members as of May 2020 and, through the operation of Communities of Practice and different face-to-face and virtual activities, provides spaces for exchange, dialogue and collaboration among government experts, non-governmental and international organizations on issues relevant to resilient and low-emission development. The Platform Secretariat is operated by Libélula Institute for Global Change.

The Bio-E Cop, co-organized by LEDS LAC and the LEDS GP Energy Task Force, brings together government leaders, the private sector, academia, and international organizations working on the sustainable development of bioenergy in Latin America and the Caribbean. The CoP facilitates exchange and collaboration and coordinates technical assistance from the Climate Helpdesk and other partners for its members.

Agrogeneradora, a subsidiary company of Grupo Central Agrícola, as a member of Bio-GroupE Cop requested support for the review and issuance of comments and recommendations on the technical and financial analysis of technological alternatives for the valorization of the biogas by-products. In response to this request, the Climate Helpdesk and the Secretariat of LEDS LAC coordinated the recruitment of the Universidad Austral de Chile, an institution that has prepared this document as a result of its technical assistance.

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INTRODUCTION

Agrogeneradora, a subsidiary company of Grupo Central Agrícola, is the first project in Guatemala that uses livestock waste from the poultry farm to generate energy, both heating and electricity, from biogas co-generation. That represents an efficient way of managing the wastes by obtaining digestate, which being processed as fertilizer, represents an asset for the company. It is estimated that 10% of this production will be marketed as an organic amendment aimed at the retail market (B2C), without altering its chemical structure. On the other hand, 90% will be administered supplemented with mineral fertilizers, according to the requisite of farms (B2B) production of Chinese peas, broccoli and potatoes.

The objective of this study is to agriculturally evaluate the advantages and disadvantages of the amendment and mineral-organic fertilizer based on digestate, in addition to the prices at which they can be sale. Furthermore, technical-environmental and economic aspects of drying / dehydration of biodigestion by-products systems were evaluated, based on the technical approaches and proposals requested to 3 industrial machinery companies (A, B and C). Every aspect evaluated was ranked using PROMETHEE, a multi-criteria decision analysis, in order to give an orientation towards the best alternative.

ANALYSIS OF FERTILIZERS TO BE COMMERCIALIZED

Organic amendment based on digestate provide important benefits to the soil system, as it allows the increase of bacterial activity, provides nutrients and delivers organic matter [4]. However, the amendments present a large variability in their nutritional content because they contain mineralized nutrients in various forms and others are organically linked, with a slow mineralization. This, compared to mineral fertilizers, results in differences in availability over time.

Considering the soil nitrogen balance as the difference between the extractable N (available) and the total amount of nitrogen applied from the digestate, an amount of nitrogen will not be available to be absorbed by the crops in the first year of its application, given its use by soil biology to degrade fresh organic matter. Therefore, the NH_4^+ content of the digestate cannot be considered equivalent to mineral fertilizer. It has been shown that there is a synergistic effect of supplementation with mineral fertilizer that allows ecological efficiency[1] in fertilization [5]. This, because mineral fertilization can supplement the amount of nitrogen that is not available immediately after the application period. Thus, these disadvantages of availability performance deficiencies can be compensated by combining organic fertilization with mineral fertilization [2] [5] [6].

Nutritional content and fertilizer selection

The nutritional contents of the amendment from the digestate present a fertilizer behavior of 6-4-4 (6% N, 4% P and 4% K) whose formulation indicates that its potassium levels are very low, which makes it a fertilizer that allows to increase the levels of phosphorus in the soil.

On the other hand, if we consider that 50% of the nitrogen content, 90% of the phosphorus and 95% of the potassium will be available in ther first year,, in real terms we obtain a fertilizer 3-4-4, which could be applied at the beginning of fertilization as a corrector, to then be supplemented with the application of a nitrogen fertilizer for the growing season.

The nutritional demand of vegetables and plants in general is about 5 times higher nitrogen than phosphorus; for potassium, the N/K ratio is 1/2 to 1/0.5. Therefore, an 8-3-8 fertilizer is recommended because it is similar to the plant demand, , and therefore to the

[1] Ecological efficiency (ökologische effizienz) is the relationship between the energy or biomass available and actually used by one or more organisms, in the food chain or ecosystems.

requirement of vegetables producers. This fertilizer is recommended in soils that have a good fertility base.

Alternative cost of digestate

According to the nutritional contents of commercial fertilizers evaluated and their market prices, the price of a mixture of fertilizers that provides the same amount of nutrients as a metric ton of dry digestate was calculated. This resulted in a price ranging USD 100-150 per metric ton of amendment. These prices were calculated considering a realistic scenario with a release of 50% Nitrogen, 95% Phosphorus and 90% Potassium at the first year and, an "optimistic" scenario with total release.

Granulation or palletization of the product

The palletization of digestate is attractive for the two type of clients identified in the market study. In the case of B2C, the digestate pellets can be optimally sale in smaller packages in garden centres and DIY shops. Because of their cleanliness, they are easy to use for the end customers [2]. As regards the B2B market, due to the fact that Chinese pea, broccoli and potato crops have a higher planting density in relation to grassland and cereal crops; the use of pellets allows fertilization with a more precise dose, better localized (individually per plant), more efficient and therefore with lower fertilization costs.

ANALYSIS OF TECHNOLOGICAL ALTERNATIVES OFFERED

Biogas aggregate value, and energy efficiency

The electricity and heat cogeneration from biogas, can reach efficiency rates over 80% at industrial level. On the other hand, the drying of sludge by biogas combustion may achieve higher energy efficiencies. However, the energy produced is only heat and its market price is low compared to electricity.

According to the above, the supply of biogas energy was estimated at 28714 m3/day, which allows an electric power of 2722 kW and thermal of 3500 kW through cogeneration. Regarding the electrical demand, we consider 351 HP of power (263 kW of electrical consumption assuming 100% of the engines in operation).

Regarding the thermal energy demand, a power of 2604 kW was calculated, considering a drying efficiency of 0.7 kg / kWh (evaporation). This way, when compared that heat with the thermal supply from cogeneration, it is noted that the available heat reaches what is demanded.

Finally, by comparing economically the alternatives with and without the use of biogas in the process, a range of annual costs is obtained from over USD 4 million (purchase of 100% of energy as electricity) to a net profit over one million USD (0 purchase of energy and sale of surplus electricity).

Technical analysis of alternatives offered

A technical analysis of the three engineering companies for the waste management and fertilizer production plant is presented below.

Company A. The proposal corresponds to a drying/dehydrated Optiplate system. This system is compatible with the use of residual heat from biogas cogeneration, given its basis in a forced flow of hot air. However, the system offered is designed from a system for drying manure. Although the solid fraction of digestate may have similar characteristics to manure, it cannot be guaranteed its optimization on anaerobic digestion process, even if the equipment is calibrated for such differences.

Company B. Like Company A, the drying system is through belts / plates traversed by forced airflow. However, the company focuses specifically on digestate drying, through a heat / air exchanger, and subsequent air transfer to the dryer. This way, it offers a system that uses residual heat from cogeneration. Additionally, this alternative is especially interesting regarding the recovery of nutrients from the liquid fraction of the digestate that can constitute a high percentage of the total nutrients.

Company C. The proposal corresponds to a dryer/dehydrator that combusts biogas, which can be the cheapest investment, but may involve important economic losses by not taking advantage of the residual heat from cogeneration.

Moreover, such combustion drying system can reach high temperatures, which would not be optimal neither for the pelletizing process nor for the fertilizer quality. On the contrary, a heat exchange system from hot water will hardly exceed 100 º C, ensuring the good quality of the process.

Weighing

For the analysis of technical information, the results were weighted within qualitative - systemic criteria through values ranging from 1 to 5 (1 = very bad; 2 = bad; 3 = fair; 4 = good; and 5 = very good).

Table 1. Technical-environmental criteria by technology.

Technical and Environmental Performance	Technologies		
	A	B	C
Experience in digestate/biogas treatment	3	5	? (2)
Experience in poultry production systems	5	4	? (4)
Pelletized	5	5	? (4)
Drying system	5	5	2
Energy Efficiency and carbon footprint	4	5	2
Information on the website	4	5	1
Fertilizer recovery efficiency (pollution by liquid industrial waste)	? (4)	5	? (4)
Weighing	4,3	4,9	2,7

In this way, considering only the aspects strictly linked to the integration of anaerobic digestion process with waste management, the possibility of taking advantage of the biogas residual thermal energy, and the experience in handling digestate through drying and pelletizing, the best option is company B, followed by A.

Economic analysis of alternatives offered

In this study, the economic indicators IRR, NPV and PBP[2] for the three companies (A, B and C) were analyzed for the amendment and organo-mineral fertilizer options. In addition, two scenarios were considered for each option, one with a 10% annual increase in sales (1) and another with 20% (2).

As it can be appreciated in tables 2 and 3, the most economically interesting alternative is the A2 scenario, followed by the B2 scenario, with a NPV difference of approximately 10%.

Table 2. Financial indicators for amendment commercialization.

Company - Scenario	Financial indicators		
	IRR	NPV (USD)	PBP
A1	37,37	299.540	4,95
A2	46,29	409.928	3,8
B1	30,28	247.443	5,4
B2	38,05	356.014	4,29
C1	14,76	49.265	7,1
C2	20,25	152.738	5,92

Table 3. Financial indicators for the commercialization of mineral-organic fertilizer.

Company - Scenario	Financial indicators		
	IRR	NPV (USD)	PBP
A1	25	260.882	5,61
A2	30,92	396.340	4,67
B1	10,85	186.079	6,07
B2	28,33	359.658	4,94
C1	15,54	64.415	6,81
C2	30,92	396.340	4,67

On the other hand, when calculating the operating cost at which the Net Present Value is 0, the scenario that allows higher operational costs is A2, followed by B2 for the Amendment option. The C1 scenario is the least likely to increase operating costs. The same ranking is obtained for the analysis of the mineral-organic fertilizer (table 4).

[2] Respectively: Internal Rate of Return, Net Present Value and Payback Period

Table 4. Increase in operational cost (USD/year), to which the NPV becomes 0.

Company - Scenario	Amendment	Fertilizer
A1	54.500	50.850
A2	74.500	77.300
B1	45.800	36.800
B2	66.000	70.250
C1	9.500	13.000
C2	29.800	77.300

Selection of technological alternatives

In this study, the method Multicriterial Decision Analysis [1] was applied using the software PROMETHEE [3] with partial classification of Promethee I and Promethee Ranking. This allowed us to choose the best technology offered by the companies, regarding which of them allows greater benefits in the processing of amendment and mineral-organic fertilizer.

In the analysis, the financial indicators IRR, NPV and BPB were considered with an allocation of 60% relative importance (20% IRR, 20% NPV, 20% PBP) and 40% for the weighing of the Technical-Environmental Performance for each company. Results are shown in figure 1.

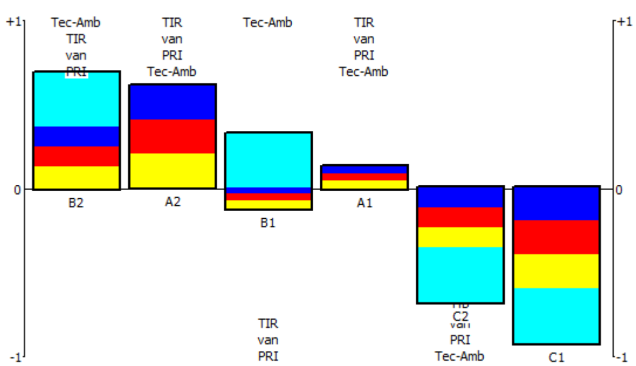

Figure 1. Promethee Ranking for different technologies and scenarios in commercial fertilizer production. Parameters on the graph indicate advantage, and under the graph, disadvantage.

With such precedents, the results of priority choice of the different technologies were compared, in order to verify if the selection of companies varies depending on whether it is amendment or mineral-organic fertilizer. However, for such analysis Promethee gives the same ranking. The final score results are given in figure 2.

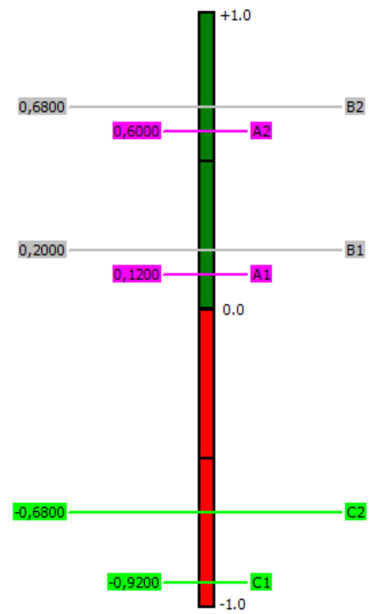

Figure 2. Promethee ranking for the different technologies in the production of mineral-organic fertilizer.

CONCLUSIONS

In relation to the commercialization of digestate; as an amendment or an organic-mineral fertilizer, it is concluded:

- The amendment has low nitrogen and potassium contents, in addition to a low rate of nutrient release to the soil. This is due to the speed of mineralization and the content of organic matter, whose degradation demand nutrients from the soil microorganisms.
- In the case of nitrogen, a maximum 50% should be available in the first year, and 19% in the second, until it is fully available in year 7 to 9.
- Therefore, raising the amendment doses to compensate the low nutrient content does not

totally solve the problem, especially in the first months after its application to the soil.

- On the other hand, the quantity cannot easily be increased, since the low concentration of nutrients would force to transport large volumes of amendment, which implies high costs.
- In this regard, pelletizing is a good option both for the amendment and for the mineral-organic fertilizer, since it reduces the volume via compression, especially when the distances are far. In addition, it improves concentration, homogeneity, ease, and precision in its application.
- The amendment option has good characteristics for the B2C market and would work as a good "starter", that is, a fertilizer to raise the base nutritional levels of the soil.
- Regarding the availability of nutrients, the mineral-organic fertilizer would be a good solution, since, in addition to the amendment, it contains quick mineralizable nutrients (ammonia nitrogen). Therefore, the release curve of the fertilizer in the soil would be much closer to the crop nutrient demand curve.
- Consequently, the mineral-organic fertilizer is the most appropriate option for the B2B market, considering good soil fertility base levels. In this case, the fertilizer would be focused on cultivation, and not on soil correction.

In relation to technological alternatives, when evaluating the 3 proposed alternatives, it is concluded:

- The technical-environmental analysis was based on concepts of energy efficiency, carbon footprint and nutrient recovery. In this regard, the feasibility of using cogeneration heat from biogas is key, as well as the separation and purification systems for the different phases of the digestate. These issues are also directly related to the economic component, despite the fact that they have not been directly considered in the financial studies, which is why they are addressed in this report in a preliminary manner.
- From a technical-environmental point of view, it is confirmed that company B would be the best alternative, followed by company A.
- From an economic point of view, including the IRR, NPV, and PBP financial indicators, as well as the operating cost margin, company A would be the best alternative, followed by company B, while alternative C would be the worst evaluated in both technical and economic terms.
- When using an overall multi-criteria (interdisciplinary) ranking, the best of the 3 options would be company B.

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