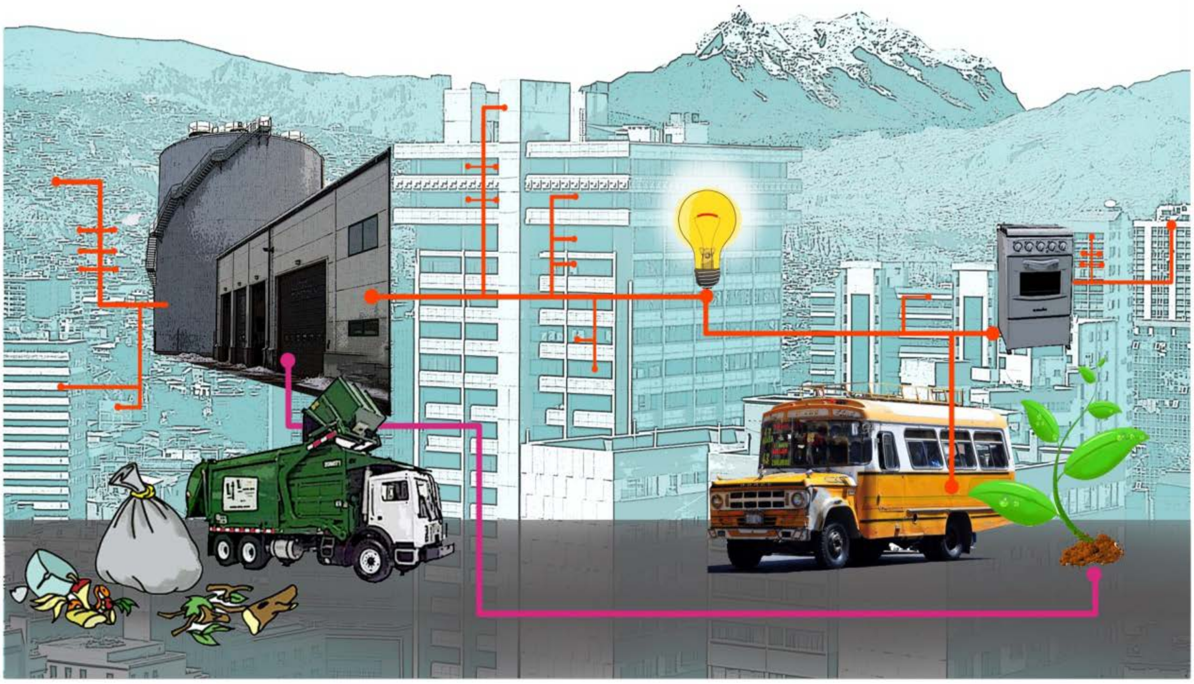
15 July 2014

Implementing Waste-to-Biogas in Bolivia

Summary for policy makers



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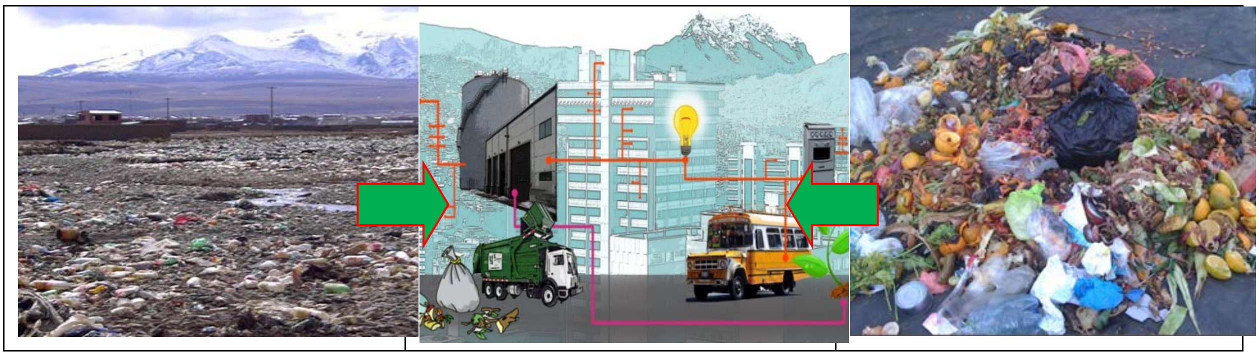
1. Introduction

Solid waste management has emerged as one of the major environmental problems of cities all over the world. The consequences of inappropriate waste management are manifold, including environmental hazards such as air pollution and water contamination, negative impacts on public health, and greenhouse gas emissions. Fortunately, opportunities exist to reduce environmental and social impacts of waste through modern and well-proven management practices. Anaerobic digestion of solid organic waste can generate biogas for multiple purposes, e.g. cooking, transport, heating or electricity, and bi-products can be used as fertilizers if the waste collection is properly managed.

The project *Waste-to-Biogas in Bolivia – Promoting Sustainable Development* developed in collaboration between Swedish and Bolivian organizations between Dec 2011 and May 2014 brought important insights about the opportunity to develop biogas systems in La Paz and El Alto. The analysis included a waste characterization study, a stakeholder dialogue and identification of barriers that need to be overcome to realize the existing potential. In addition, the policy frameworks affecting the attractiveness of biogas in Bolivia, and potential funding options for biogas schemes were evaluated. The climate benefits were calculated in the case of La Paz, indicating the great attractiveness of biogas schemes to address climate mitigation in urban areas of Bolivia. The project proposed a strategy to establish biogas schemes in the metropolitan area. Since the biogas technologies at the scales proposed are not yet available in Bolivia, such schemes can also help promote technology transfer and dissemination in the country as a whole.

Figure 1: Waste-to-energy in Bolivia offer opportunities to promote sustainable development

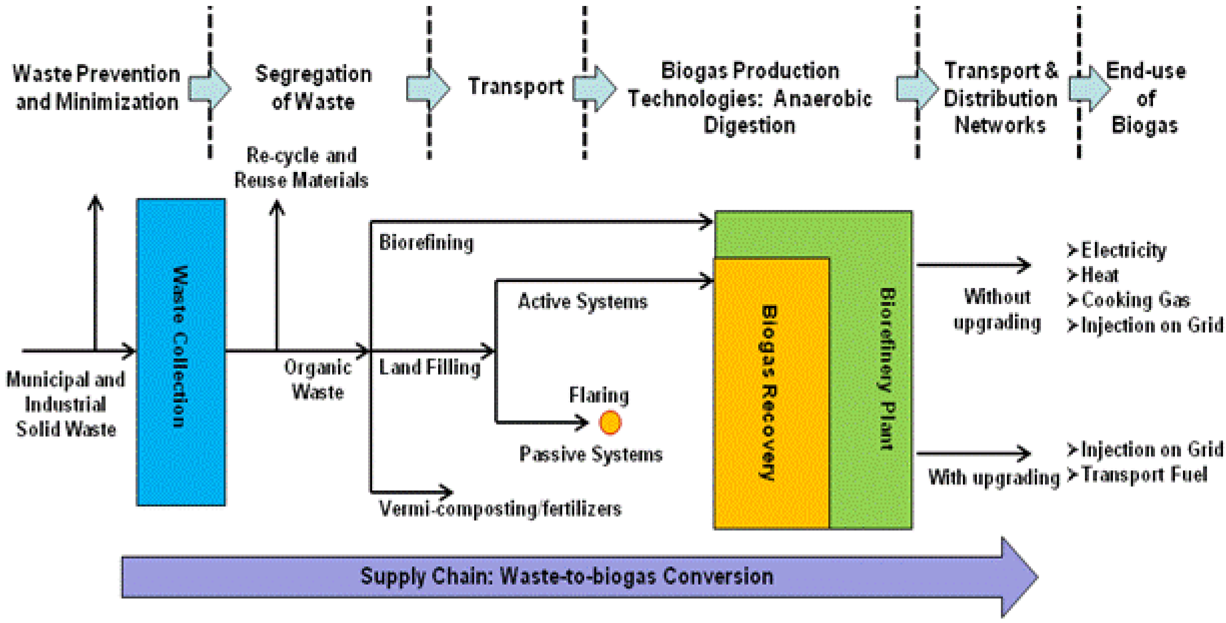


The project was led by KTH and implemented by Swedish (KTH, MDH, VAFAB) and Bolivian (NUR, CPTS, UMSA) partners. In addition, the municipalities of La Paz and El Alto as well as operating companies along the waste management chain, and ministries in Bolivia have provided invaluable information and support along the process. The project was funded by the Nordic Climate Facility (NCF) which is financed by the Nordic Development Fund (NDF) and implemented jointly with the Nordic Environment Finance Corporation (NEFCO).

2. Biogas supply-chain and service provision

A schematic illustration of the supply-chain of waste-to-biogas is shown in Figure 2. Waste prevention and minimization is important to achieve over time. However, large quantities of waste are being generated every day which can be put to better use rather than simply be deposited in landfills. Non-organic parts of the waste can be recycled including cardboards, plastics and glass. The organic portion of the waste serves to generate biogas. The gas can be used to produce electricity or, if upgraded, is equivalent to natural gas as transport fuel. The digestate is a bi-product in the biogas anaerobic digestion (AD) plant and can be used as fertilizer. If the organic waste is separated by the household before collection, no contamination occurs, and the derived digestate is valuable organic fertilizer that can be used for food production. To achieve this valorization of the waste, it is necessary to organize the waste separation and collection to maximize the amount of biogas produced, the quality of the digestate, and the overall commercial value of the products and services along the process.

Figure 2: Supply chain and solid waste management systems for waste-to-biogas



It is possible to start biogas production and utilization before the sorting of waste at household level is operational. The biogas present in the landfill can be actively extracted and used for electricity production, for example. The common practice in La Paz and El Alto today is to capture the landfill gas through passive extraction, and flare the biogas. Thus no energy is being recovered from the process, and valuable resources are being lost. In addition, a biogas plant based on mixed waste can be established. The digestate of such a plant can have multiple applications such as fertilization of gardens and forests or be used in erosion control.

Household waste composes most of the waste being collected in the metropolitan area. About half of the waste is organic matter that can be used for biogas generation. From a technical point of view, there are tangible opportunities to implement an active landfill extraction in La

Paz and El Alto and to develop a full system for transforming waste-to-biogas. This will require leadership of the local authorities to mobilize the stakeholders involved in waste management (e.g. companies and waste segregators), allocate investments, create the right incentives and favourable environment for technology acquisition, and finally gather enough effort to establish a waste-to-biogas system.

3. Solid waste management in Bolivia

The management of solid waste in Bolivia is oriented towards the management of services to collect, transport and deposit the waste in landfills. In some cases, there is appropriate waste disposal such as in the metropolitan area, but many technical and environmental deficiencies exist in most municipalities. There is need to move forward making new efforts to reuse, reduce and recycle materials, while also dealing better with waste disposal and valorization.

The rapid growth of cities of intermediate size has led to dramatic increase in the demand for waste management services, rapidly exceeding the prevailing technical and financial capacity of municipalities. The estimated average residential solid waste production is 0.50 kg per capita-day in urban areas of Bolivia, and 0.20 kg / capita-day in rural areas. Some 55% of this waste is organic or bio-degradable material, 22% is recyclable material and 23% is considered unusable material. In 2009, the total waste generation in urban areas was 1,677,650 tons / year (4,569 ton/day) of which 85% were generated in urban areas and 15% in rural areas. Some 45% of the waste is disposed in landfills of main cities, and the rest is simply disposed in open dumps.

Solid waste policy is still at an early stage in Bolivia and many actions are needed to develop a robust strategy and improve efficiency in waste management. Since 2009, the country has a Directorate of Integrated Solid Waste Management (DGGIRS) in charge of developing the national policy for the sector. The first tasks of DGGIRS are the closure of landfills, implementation of landfill management and development guidance for environmental education. In addition, DGGIRS is developing the framework law for solid waste management that defines obligations related to the disposal and utilization of solid waste. The bill is being evaluated by various departments aiming for approval by the Council of Ministers and the President in 2014.

Meanwhile, actions by municipalities in the metropolitan area can serve to demonstrate innovative policy, technologies and financial modalities for waste management. These actions may include adoption of new models for waste management, new technologies for waste treatment and valorization, and schemes for cost-recovery. The majority of municipalities subsidize sanitation services and solid waste management heavily. Only 54 (17%) of Bolivia's 327 municipalities charge for the waste management services through trash collection fees that cover only 40% to 60% of operating costs. The shortfall is generally subsidized through municipal budgets. Obviously, the local cost-recovery system needs to be revised aiming at a solid economic model for waste management services. According to the Autonomous Law, local governments can design their own waste management models and tariff systems.

4. Opportunities for biogas in La Paz and El Alto

La Paz and El Alto have organized solid waste collection and landfills that can serve as starting point for biogas production. Both municipalities have initiated pilot projects aimed at improving waste management. Actions include separation of portions of the waste, composting, and recovery of recyclables. Improvements in waste management can bring many benefits to the metropolitan area while also contributing to the implementation of the climate agenda. The challenge is to devise and implement sustainable methods to manage solid waste from separation of organic and recyclable materials to the collection and transport of the waste, and final processing for useful applications. The ultimate goal should be to phase-out organic waste deposition.

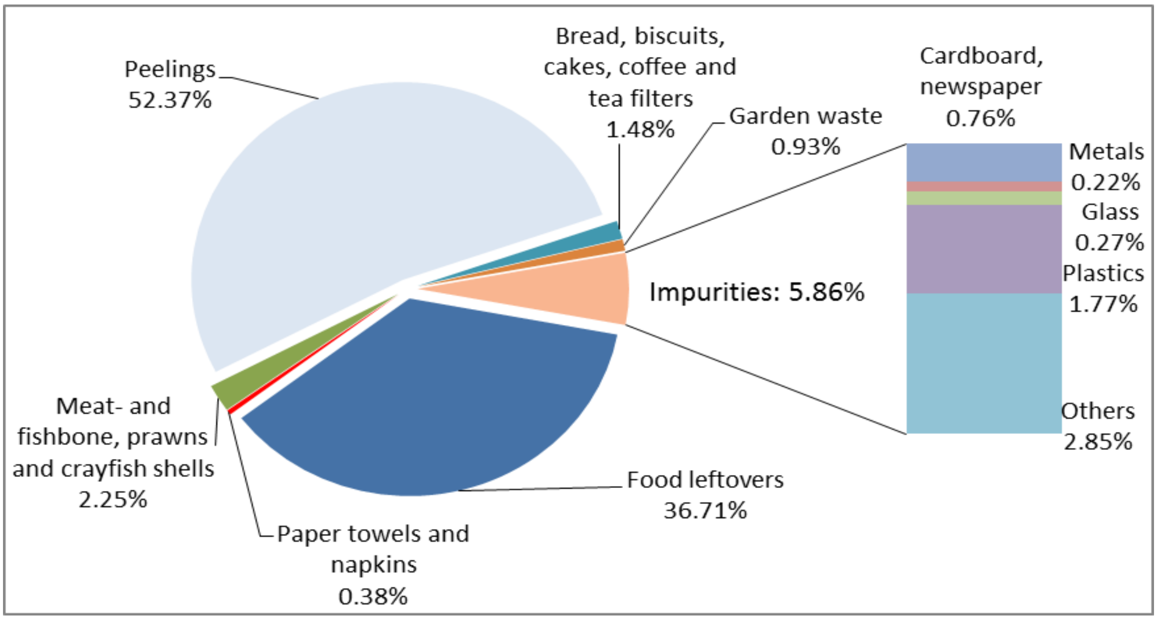
As the municipal landfills approach full capacity, the need to find other waste management options becomes imminent. Currently, approximately 80% of all household waste in La Paz and 95% of the waste in El Alto are disposed in the landfill sites of *Alpacoma* and *Villa Ingenio* respectively. *Alpacoma* has been in operation since 2006 and is expected to continue operations for another 14 years. *Villa Ingenio* includes two distinct areas, one in the process of closure and the other in operation. The landfill shall reach maximum capacity by 2015.

The share of organic waste is the basis for calculating the biogas production potential. Together, La Paz and El Alto generate approximately 20% of the municipal solid waste in the country. A waste characterization study carried out in 2012 indicated the biogas potential in the two municipalities. La Paz has a population of 0.84 million inhabitants generating 486 t/day municipal solid waste. El Alto has a population of approximately one million inhabitants generating 292 t/day. Approximately half of the waste is organic. The composition of the organic waste in the two municipalities is shown in Figure 3. Garden waste is not common in El Alto due to the altitude – otherwise the waste content is rather similar. Although it is presently mixed with non-organic waste, the analysis of parameters relevant for biogas production and digestate quality indicated suitable chemical composition justifying serious consideration of biogas schemes as part of new waste management options.

The field study provided also insight about the attitude of households towards waste sorting. The vast majority of households indicated willingness to segregate waste regardless the economic strata. It should be noted that the organic waste was separated by the households themselves before collection for analysis. The households only received a 2-minute instruction on how to segregate organic waste. The amount of impurities found in the samples collected during the study was quite low (less than 4% in La Paz and less than 6% in El Alto), confirming the cooperative attitude of the population. This is very promising and good indication of the viability of obtaining public support for organizing segregated waste collection in the metropolitan area.

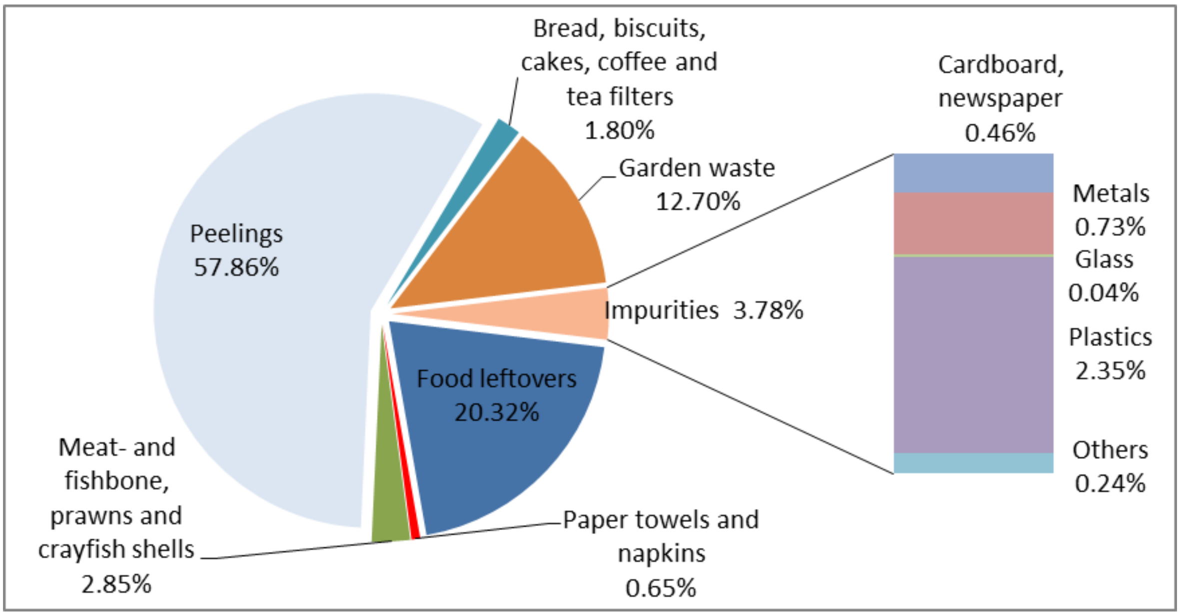
Figure 3: Composition of organic waste in El Alto and La Paz (study carried out in 2012)

El Alto



Note: Average for all social strata, based on a weighted mean value

La Paz



Note: Average for all social strata, based on a weighted mean value

5. Climate benefits of waste-to-biogas

Various benefits can be accrued from the transformation of waste into biogas. Benefits include extension of the lifetime of present sites for waste deposition, reduction of greenhouse gas emissions, generation of electricity, production of organic fertilizers, and opportunity to acquire and demonstrate a technology with significant replication potential in the country. The climate benefits were calculated for La Paz, indicating the attractiveness of biogas schemes to address climate mitigation. Although no techno-economic analysis was made for the case of El Alto, the circumstances are quite similar in both cities.

Different scenarios were evaluated for waste-to-biogas systems in La Paz, and their related greenhouse gas (GHG) emissions reduction potential. The analysis indicates an enormous amount of lifecycle GHG emissions being released in *Alpacoma*. In its present form, the passive landfill shall emit approximately 1.83 million tCO_{2eq} (over a 100 year period) if we consider a partial biogas flaring of 20%. As the biogas collection improves and its utilization for energy production increases with active gas extraction in the landfill, net emissions can be reduced. If 25% and 50% of municipal solid waste is sorted by 2015 and 2020 respectively, and the organic waste diverted into an anaerobic digestion (AD) plant for the production of biogas and organic fertilizer, *Alpacoma* can serve as landfill until 2027.

Figure 4: Alpacoma landfill in La Paz

A separation plant has been recently established in *Alpacoma*

New residential areas being open on the other side of the landfill.

Alpacoma, where household waste from La Paz is deposited – 486 t/day

The net lifecycle GHG emission savings with a combination of active biogas extraction and AD plant is 524,920 tCO2eq if the biogas is used for power generation and 539,507 tCO2eq if the biogas is used as fuel in transport. The organic fertilizer contributes 18,191 tCO_{2eq} GHG emissions savings while carbon sequestration would be 17,412 tCO_{2eq}, considering that 10% of carbon is stored in the digestate. The net lifecycle GHG emission savings occur due to avoided landfill emissions, replacement of fossil fuel with biogas and reduction in synthetic fossil based fertilizer. Emissions due to waste transport and equipment operation at the landfill site are negligible.

The lifecycle emissions vary depending on the physical characteristics of the waste (sorted or mixed), recycling, composting or biodigestion, different technological options (waste management practices and conversion technologies), derived energy products and co-products, and service substitution. Uncertainties depend also on factors such as methane generation parameters, gas extraction efficiency and utilization, leakages, and the type of substituted fossil-based products or services by outputs from the waste-to-energy conversion. For a more accurate estimation of GHG emissions, it is important to analyze and simulate the various management and technological options. In our analysis, we have considered 1% fugitive emissions in the biogas AD plant, which would result in net emissions savings of 68,989 tCO_{2eq} if biogas is used to generate electricity and substitute natural gas. If the fugitive loss reaches 15%, no net lifecycle GHG savings are achieved. This means that avoiding leakage of methane/biogas is essential from a climate change point of view.

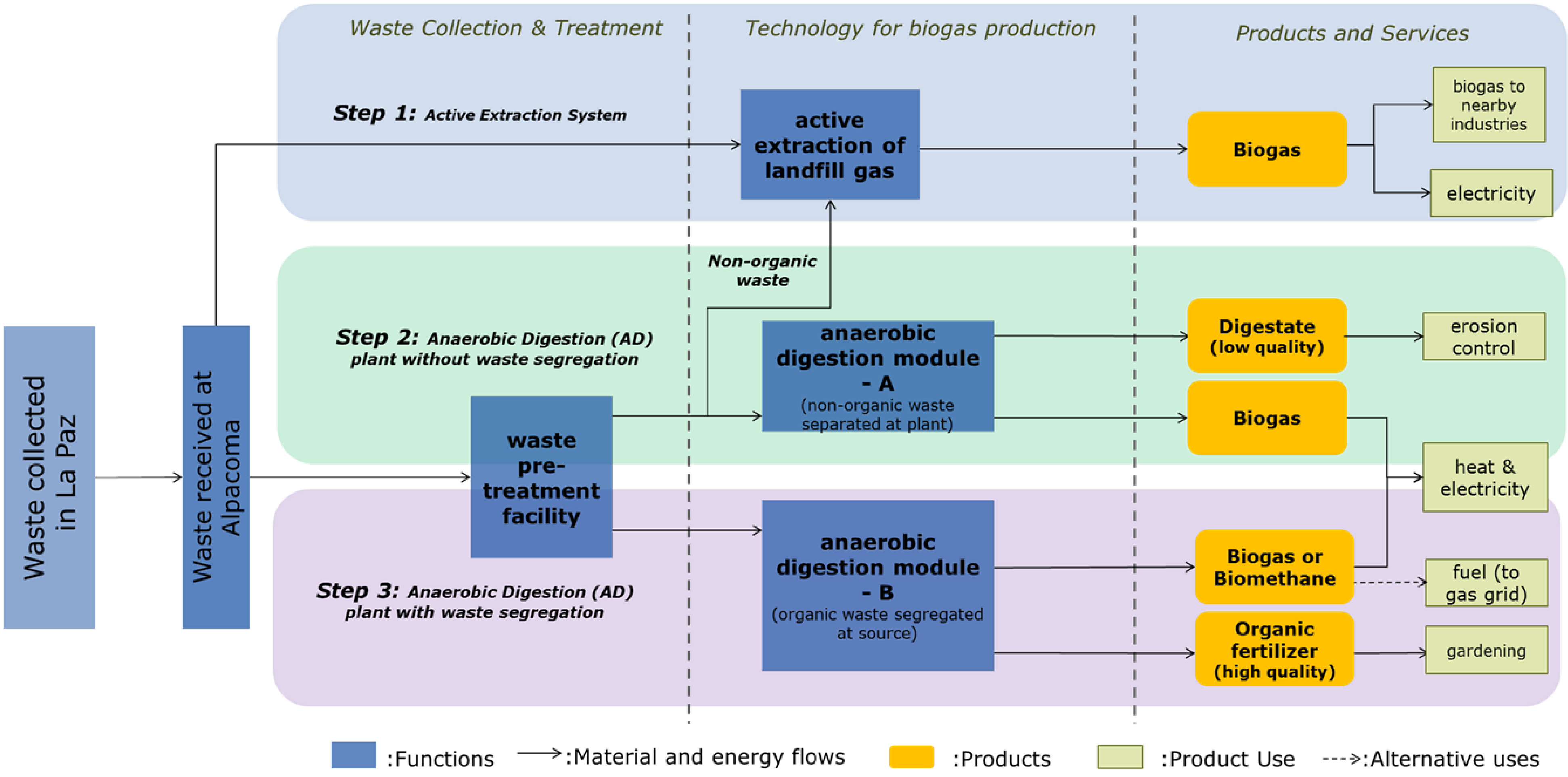
In summary, waste-to-biogas conversion offers opportunities to mitigate climate change while generating renewable energy and other bio-based products such as organic fertilizer. The analysis indicates that it is worthwhile formulating strategies for improved waste management practices and treatment options in La Paz and El Alto aiming at optimal resource/energy recovery and climate change mitigation. Both short-term and medium-term plans will be needed to implement new solid waste management practices, mobilize investments, and market the energy services and products generated from organic waste.

6. A strategy to implement biogas schemes in Bolivia

La Paz and El Alto generate together one fifth of the waste from households in Bolivia. Thus a scheme that contributes to the valorisation of the waste is likely to have a significant impact both locally and nationally. Based on the analysis carried out and the policy context of Bolivia, a strategy is proposed for implementing waste-to-biogas in three steps. The strategy is derived from investigation of the most favorable solutions for converting waste-to-biogas in La Paz, considering commercial technological know-how, waste generation and composition of organic waste within the municipalities, local arrangements for waste management, and investment opportunities available to support the implementation of a biogas strategy.

We propose to start the biogas production in *Alpacoma or Villa Ingenio* in three steps s shown in Figure 5. *Step 1* consists of an active gas extraction system in the landfill. The landfill continues producing biogas long after its closure, though in decreasing amounts. *Step 2* implies the establishment of a dry-digestion biogas facility based on present waste collection practices (using mixed waste). *Step 3* consists of a biogas plant using dry digestion for processing biowaste separated at source. New modules are gradually added to the plant depending on organic waste availability. The transition from *Step 2* to *Step 3* is possible with minor modifications in the plant. Thus the AD plant will initially receive mixed waste as feedstock, and the non-organic waste that is not recycled will still end up in the landfill. The segregation process is gradually established and fully integrated into the waste management system, so that the anaerobic digestion plant eventually only receives organic feedstock. The need for landfilling is gradually reduced.

Figure 5: Schematic diagram for the waste-to-biogas strategy in La Paz and El Alto



The analysis shows that the Internal Rate of Return (IRR) of the landfill biogas project is not so attractive (3.5%) under a business as usual scenario. The NPV is negative mainly because of high investment costs and low market price for electricity. In fact, electricity prices and investment costs have significant impact on the economic feasibility of the active landfill biogas project. The price of electricity is very low in Bolivia due to subsidies applied to natural gas. 10% increase in the electricity price gives an IRR of 5.5 (the discount rate used was 5%). If the electricity price is increased by 50% (i.e. 0.09 USD/kWh) the active extraction of landfill gas for electricity generation becomes an attractive option.

The NPV becomes positive if the investment cost is reduced by 10%. The IRR will be 10% at a 20% decrease in the investment costs. Since the sale of electricity is the only income source in *Step 1*, the economic viability of *Step 1* is contingent to energy subsidies being extended to biogas unless subsidies to natural gas are reduced. However, GHG emissions and other local environmental pollution are greatly reduced, which could affect the project feasibility if emissions reductions and environmental quality are prioritized. Interestingly, if we consider waste-to-biogas conversion in the landfill as a carbon abatement project, a carbon price of 10 US$/t$CO_2$ would lead to an IRR of 27%. In this case, the project would become a very attractive option for carbon abatement at competitive prices.

Clearly, energy sales alone are not enough to balance the cost investments in *Step 1*, due to current energy prices. Waste transportation fees, waste handling and treatment fees, and revenues from the sales of organic fertilizer together can make the project viable. This was the case in *Step 2* and *Step 3*. Among all variables studied, the price of electricity is the one which affects the feasibility of biogas the most. The closer the electricity price is to price levels in Europe or in the isolated electricity system in Bolivia (0.14 US$/kWh), the higher the economic feasibility of the biogas. In addition, using organic waste separated at the source in the AD plant is more attractive economically compared to mixed waste because of the high quality organic fertilizer (digestate) resulting from the digestion process. This assumes a market for the organic fertilizer.

From an economic point of view, biogas technology using segregated waste at the source is the most attractive option. This also implies significant reduction in the amount of waste going to the landfill. However, waste separation in the households will require some planning, information campaigns and adaptation of the collection system. This step comes with the challenge of more complex logistics and investments. In any case, it is important to decide about how the biogas will be used e.g. to produce heat, electricity or fuel for transport, since this will affect the total economy of the scheme. Also the destination of the digestate needs to be considered as it affects the choice of waste sourcing and technology. The digestate from sorted organic waste is high quality organic fertilizer that can possibly reach good value and substitute fossil-based fertilizers. Still, creating a market for the organic fertilizer may require collaboration with farmers and/or farmers’ organizations. For this purpose, the participation of the university will be very useful for analysing the quality of the digestate, monitoring results and giving credibility among different stakeholders.

7. Factors affecting the attractiveness of biogas

There are clear opportunities to realize the biogas potential identified in La Paz and El Alto. However, a number of barriers need to be overcome so that biogas can be implemented and the benefits captured. The barriers include the need for technology transfer and adoption, stakeholder coordination, allocation of funding for investments, and regulatory frameworks to facilitate the formation of markets for biogas and organic fertilizers.

Policy barriers include subsidized natural gas which crowds out other energy options. Social and economic barriers are felt in popular resistance to higher waste fees and lack of awareness regarding environmental impacts. Institutional barriers are felt particularly when it comes to the definition of a common agenda to catalyse national and local goals, and the efforts needed from various stakeholders. Other institutional barriers include lack of regulations to promote the valorisation of waste to energy. Technological barriers are found in the lack of expertise in the biogas field and lack of demonstration plants in the country in the scales required. Cooperation among actors is crucial at various levels to make biogas a viable proposition. The municipality has the possibility to catalyse the process and help overcome the transaction costs implied when linking stakeholders along the supply chain, attracting investments and mobilizing the population.

It is important to conceive the waste-to-biogas schemes as an overall strategy to reduce waste generation and to valorise it. Segregation of materials has started particularly of plastics and metals as these already have a market value. This is gradually reducing the amount of waste to be handled at the landfill but the organic waste is still not being used. If the biogas scheme is implemented, organic waste deposition can be phased-out by 2025 in both municipalities. However, since *Villa Ingenio* is expected to reach maximum capacity by 2015, there is need for a new site for waste deposition in El Alto. A new site has been identified but there is still need for infrastructure to make it operational. The site is further out from the city and thus logistics will have to be rethought in order to optimize the location of the biogas plant.

Making the waste-to-biogas program attractive and eligible for funding within local, national, bi-lateral or international financial mechanisms is important for disseminating the practice in Bolivia as a whole. Unfortunately, the country's business environment reduces attraction for investments to promote waste-to-biogas. In addition, prevailing policies are detrimental to the exploration of renewable energy alternatives. The high subsidies provided to natural gas and the related low electricity costs are in direct contrast with the need to diversify the energy matrix, and the ambition to develop renewable energy, and reduce environmental impacts.

Nevertheless, there is increasing understanding about the need to coordinate efforts in waste management. Some on-going national and municipal policy efforts may serve as the basis for promoting biogas. Two policy forces favour the development of waste-to-biogas in Bolivia. The first is related to the objective to reduce greenhouse gas emissions. The second is related to the need to solve problems of solid waste disposal and treatment at the municipal level.

A stringent climate agenda is being put in place in Bolivia and a national trust fund is in place. Sector or programmatic approaches are suitable for advancing integrated waste management including waste to biogas within the context of climate policies. If the link is made between climate and waste management policies both at national and local levels, the opportunities for funding can be enhanced through climate funds. There are different options for funding biogas projects in multilateral and commercial banks. However, accessing global climate funds is problematic due to the present position of the Bolivian government against market based mechanisms under the climate convention (UNFCCC).

When it comes to a solid waste strategy, it is the role of the waste directorate (DGGIRS) to mobilize central government authorities both within the context of the climate policy agenda, as well as the national energy and development agendas. This could bring national support to the implementation of biogas in the country as a whole. Meanwhile, actions by municipal-lities in the metropolitan area can serve to demonstrate innovative policy, technologies and financial modalities for waste management. Valorisation of residues using biogas techno-logy can reduce the costs of waste handling and contamination of the urban environment, help diversify the energy matrix, create employment and promote sustainable development.

At the moment, the amount of investment needed to implement the various steps of the strategy proposed are high in relation to the levels of annual cash flows that can be generated. However, there is opportunity to pursue cost reductions, for instance, in civil works and some parts of the plant which could be possibly made in the country. When it comes to revenues, the integration of biogas production with other related activities in the overall management chain for solid waste management requires a regulatory framework favouring the decentralized generation of electricity and/or production of transport fuels that can be injected into the gas grid. A good way to overcome these barriers is to establish long-term contracts with users, for example, bus companies for the utilization of the gas, and farmers for the utilization of fertilizers.

8. Recommendations

The use of waste to generate biogas in La Paz and El Alto can contribute to improve the local environment and wellbeing of the population, as well as to mitigate climate change. Waste-to-energy serves to create positive loops in the urban economy, while also providing an efficient way to improve municipal waste management. Furthermore, the efforts to implement biogas production in the metropolitan area can help build experience and know-how on biogas in Bolivia, which can be mainstreamed throughout the country. An additional benefit of this effort could be the development of innovative policy in waste management, including the development of instruments to promote and fund waste management at municipal level.

La Paz and El Alto are well placed to serve as starting point for a biogas scheme including extraction and use of landfill gas and establishment of an AD plant for biogas production. Our analysis indicates that institutional barriers exist which need to be addressed immediately to make the introduction of new technologies for waste management in urban areas of Bolivia possible. La Paz and El Alto have the autonomy to push for the introduction of new practices, including also new technologies and cost-recovery schemes. If methane capture in the landfill becomes a priority for municipalities in the metropolitan region together with the upgrading of the waste management system, climate funds can be assessed and the implementation of biogas can happen on a project basis at the municipal level.

Economic feasibility depends on a number of factors some of which are defined at the national level such as energy prices. Other factors can be adjusted at the local level and includes revision of cost-recovery schemes, incorporation of welfare programs linked to the waste management sector, public-private partnerships, and marketing of the products from the biogas plant. In particular, it is essential that the municipalities revise the economic sustainability of services being provided for waste collection and deposition, and also introduce new practices that can guarantee improvements over time. The introduction of organic waste separation and collection will certainly require more of the population. At the same time, it offers an opportunity to inform about waste management, introduce incentives to improve cost-recovery, invite participation and highlight the leading role of the municipality.

In this context, it is important that the municipalities of La Paz and El Alto initiate a dialogue with the concessionaires of waste collection and deposition as soon as possible to review roles and contracts, and to include them in the new schemes. The service operators involved in waste collection and deposition are key actors in this process. Also companies involved in recycling should participate. Finally, it is important not to forget the role of segregators who are collecting a portion of the waste generated in households and industry consisting of glass, plastics, aluminium, cardboard and paper. The segregated waste is often sold to intermediaries and later to recycling companies. By organizing cooperatives, work conditions and income can be improved for this group adding social value to the scheme. The universities have a role in technology and research development, monitoring and improvement of processes, capacity building and knowledge dissemination. Broad cooperation between the private and public sectors, local universities and associations to jointly introduce and develop biogas in Bolivia could be ground-breaking and institutionally innovative.

Biogas technologies are competitive proven technologies attractive for upgrading waste management systems in urban areas and commercially available. Through anaerobic digestion of solid organic waste, biogas can be generated together with valuable bi-products. Other benefits include the reduction of greenhouse gas emissions, and opportunity to demonstrate a renewable energy technology with significant replication potential in the country.

The municipality can serve as the motor to implement biogas. The municipalities of La Paz and El Alto have the autonomy to push for new practices and technologies. The international community can be called to help the municipal government put in place incentives for improved solid waste management, and design integrated schemes for biogas production and utilization, as well as overcome the key barriers to technology transfer and deployment. The climate mitigation gains are likely to be significant, thus bringing also global benefits from the effort.

Figure 6: The topography of La Paz presents a challenge for planning waste management but opportunities exist to improve waste management