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WTE INDUSTRY IN LATIN AMERICA



UN HABITAT

Executive Resume

Currently there is not a regional program leading WTE. Many countries in Latin America, for the first time, are beginning to explore the use of waste-to-energy plants as part of their integrated solid waste management plans. Geopolitical and global economic pressures have caused governments to re-evaluate how infrastructure services can be more effectively and economically procured, without degradation of quality of service and the environment. Some countries, for the first time, are passing laws enabling privatization of many historically publicly owned and operated, infrastructure services, such as electricity generation, drinking water and waste-to-energy plant ownership and operation. This is being done in an effort to gain state-of-the-art technology while lowering the cost of infrastructure services. The political events of the past ten years, and the continued emergence of a global economy, have shown the need to procure infrastructure services in a less costly way.

In order to get understanding of WTE challenges in Latin America, we should look at waste energy sectors as well as the new environmental laws, especially those that promote transition from landfill facilities to energy recovery plants by using municipal solid waste. In addition, we should evaluate the potential of WTE in making a real contribution to household access to electricity and clean cooking facilities for poor people in rural areas where waste management is not a high priority.

It is estimated that approximately 78% of the Region's population are urban dwellers. Small and medium-sized urban centers, which face the greatest difficulties in adequately managing solid waste, produce 44% of municipal solid waste (PAHO, 2007). Collection in outlying areas, where the population is generally poor and access is hampered by inadequate road conditions and infrastructure, is not a high priority. The Region's solid waste sector and its institutional framework have differing degrees of development. Ministers of health and the environment provide oversight and regulate the sector, while municipalities maintain ownership of service provision. In general, deficiencies can be observed in sector management, as well as in medium and long-term planning and programming. Municipalities typically lack management and economic capacity; notable omissions are seen in the legal framework, adequate control instruments to verify compliance and impose penalties are wanting, there is overlapping legislation—at times contradictory—and jurisdictional conflicts, and only a few countries have established specific laws dealing with solid waste. Most countries do not have comprehensive solid waste management policies, and those that do often do not enforce or disseminate them. Few countries have comprehensive plans and strategic planning for the sector, and in many it is impossible to define a national lead agency for policy and plans. The few oversight responsibilities that are fulfilled are done so in a patchwork manner by the ministries of health and the environment. Municipalities set forth regulations for household, non-hazardous industrial, and hospital solid waste, and regulate rates with some executive control. The Region's average cost for solid waste services is US\$ 29 per ton, 70% of which corresponds to sweeping, collection, and transport. The rate, however, only covers 47% of service costs, and defaulted payments approach 50%. Sector-wide investment is limited compared to that which is made in electricity, water, and sanitation. In most countries, the service is supported by collection of a municipal fee, but the fee is not only for the cleaning service; rather it is part of street lighting, property taxes, and other taxes. It is estimated that only 22.6% of waste generated in the Region is deposited in a sanitary landfill; 23.7% ends up in controlled landfills and 45.2% in open-air dumps or watercourses (PAHO, 2007). Society's participation in solid waste management is limited and is only given effective expression when there is support from non-governmental organizations. The creation of microenterprises and cooperatives to manage solid waste is

on the rise. These companies represent an economic municipal alternative, using low-cost technology and intensive labor, creating employment and fostering community involvement. Their participation in cleaning services is usually carried out with the support of non-governmental organizations. Solid waste management cooperatives, although not numerous, provide services to the poorest segments of the population.

In the case of energy, Latin America is facing a primary growth rate of 3.11% per year. It means that LAC will require a 50% increase in its installed capacity, more than 90GW in this decade. In the other hand, approximately 10% of the total population in LAC does not have access to electricity ~50 million people (Between 20% and 90% of the rural population in LAC does not have access to electricity). The Latin American renewable energy sector is almost entirely dominated by only two forms of renewable: hydro and biofuels, which make up respectively 36% and 62% share of the total of renewables (GENI, 2009). Other forms of renewable energies represent only an insignificant fraction of total energy production (1.4%). The problem itself is that these two forms of energy are not in all cases the most adequate and are, in fact, questionable in terms of their being renewable and sustainable. First of all, the hydroelectricity sector has been dominated by large hydro plants which produce almost the entire share of renewable energy in electricity generation. Large hydro plants have been constructed in Latin America for several decades now, as countries have embraced and promoted them as a means of reducing dependency on fossil fuels, especially given the large hydro potential of the region. Hydro plants have been particularly important in the production of electricity, as it represents 60% of total electrical production in Latin America. In countries like Brazil, Paraguay, and almost all Central American nations, this figure rises to more than 90% of the total. Hence, several Latin American countries have come to depend almost completely on the hydro sector for electricity. This has created problems for them on several occasions; particularly when there are extended dry periods and water levels fall significantly. Moreover, apart from creating energy security concerns, large hydro has caused serious environmental and social problems, particularly in sensitive regions like the Amazon rainforest. The construction, for example, of the Tucuruí hydro plant in the Brazilian rainforest flooded around 2400 square kilometers of rainforest and displaced around 30,000 indigenous people from their traditional territories. In this context, large hydro cannot be properly considered a form of clean, sustainable energy, particularly if viewed in the context of sustainable development. (GENI, 2009)

In the case of biofuels, its percentage share among renewables has been decreasing considerably at the regional level for the simple reason that statistical data does not distinguish between traditional and industrial/modern biofuels. Traditional biofuels are those associated with subsistence energy consumption (firewood, grass etc.), whereas industrial/modern forms concern mainly the production of biofuels such as ethanol and sugarcane. Since the 1970's, traditional biomass has decreased from 30% of total TPES to currently 15%, whereas modern biofuels have only increased slightly (GENI, 2009). Thus, as urbanization and expansion of the electric grid grows, the percentage of biomass will keep shrinking as people turn from traditional biofuels to other sources of energy. Also, both traditional and industrial biofuels have come under heavy criticism from a number of NGO's, civil groups and certain government authorities for a number of reasons. The most common concern expressed is that industrial biofuels do not contribute to reducing greenhouse gases, and they provoke a series of environmental and social problems, whereas traditional biofuels can lead to deforestation and other unsustainable practices. Although it is debatable to what extent all these criticisms are true, it is clear that biofuels are not seen as the optimal solution by some, and that it can, as can big hydro, have negative consequences. Altogether, then, it is clear that the current situation of renewables in Latin America is worse than it at first appears.

In fact, if we would take away large hydro and unsustainable biofuels production, the region will not be much better than other parts of the world. (FLACSO, 2008)

Compared with developed countries, recovery and recycling is different due to the low content of recyclable materials produced by households. An important factor is the market for recovered material because if in the surrounding areas there are no factories to reprocess them, recycling will be limited to reuse or sale to intermediaries who trade them in more remote processor plants. The decisive factor is extreme poverty that makes it necessary to become informal scavengers to survive. It is estimated that the number of scavengers in the Region exceeds one hundred thousand families involved in solid waste recovery. The degree of recycling in these countries is not known but, in general terms, it is not very great compared to the quantity of waste generated. Recycling is achieved in two ways. The first is through separation and collection in industries, businesses and large generators of homogeneous recyclable materials (paper, cardboard, bottles, plastics and ferrous and non-ferrous metals) in order to sell them to specialized private collectors. Usually, this type of recycling is profitable and environmentally positive because it can be carried out under conditions that protect the worker's health. This type of recycling program, especially glass, has achieved great success in Colombia, Mexico, and Venezuela. The Federal District of Mexico has three municipal waste separation plants with a capacity of 1,500 t/day each one, recovering 10 to 15 % of the material, as reported by the Federal District Department. The second type of segregation is practiced on the refuse itself and consists of three possible interventions: first, by scavengers who pick up recyclable items in bags or containers; second, by garbage collectors in the collection truck; and third, by scavengers in the landfill. Obviously, this form of recovery is not recommended since it usually endangers the health of the segregators, causes aesthetic problems in the city, and engenders inefficiencies in the municipal services. In general, the main beneficiaries are the intermediaries and the leaders of segregators and unions. In a recent study covering seven cities in Mexico it was found that the quantities recycled by these three types of intervention was less than 2% of all the refuse in weight. One of the problems of waste recovery is the diversion of collection trucks from their routes to discharge and sell wastes to recyclers, which increases collection costs.

In terms of biomass, since LAC are located predominantly in the warmer climates and lower latitudes, they have a considerable comparative advantage. In terms of today's utilization of biomass resources, this comparative advantage is best illustrated by the development of sugarcane resources in Brazil, mainly for ethanol but also for some industrial products such as bio-plastics. Latin America, along with sub-Saharan Africa, has been estimated as having the highest biomass potential—after accounting for food production and resource constraints—among any of the major world regions.

A fundamental issue for exploiting agricultural biomass in the future industrial bio-economy is the minimization of waste. It is common today that only a minor portion of a given crop's total biomass is actually used productively, while much is wasted. Agricultural and plantation residues form a major portion of this un-utilized or under-utilized waste stream. Ultimately, the goal should be whole crop utilization, since the bio-economy will place increasingly higher value over time on acquiring new alternative raw materials.

The traditional use of biomass refers to basic technology used, such a three stone fire or inefficient cook stove, and not the resource itself. The number of people relying on the traditional use of biomass is based on survey and national data and refers to those households where biomass is the primary fuel for cooking. However, in the last decade, Latin American countries have been working on other biomass

sources (agricultural waste, animal wastes, MSW, bio-energy from natural growth forests, and water-based biomass such as micro-algae) to innovate in bio-energy and industrial products, involving various biological, chemical, and thermal processes. The conversion can either result in final products, or may provide building blocks for further processing. The routes are not always mutually exclusive, as there are some combinations of processes that can be considered as well. Furthermore, there are often multiple energy and non-energy products or services from a particular conversion route, some of which may or may not have reached commercial levels of supply and demand.

In a few countries, agricultural waste has been used as fuel to produce heat and electricity to industrial level. In addition, there has been a tremendous impact on production of biogas as a household fuel in rural areas. Biodigesters is the best example of this biofuel produced by anaerobic digestion or fermentation of biodegradable materials such as manure, sewage, green waste. Biodigesters have been a popular option in rural areas. In fact there are a few regional programs working on biodigester as energy option: Latin American Biogas network [www. Red Biolac.org](http://www.RedBiolac.org); Biomass Users Network (www.bunca.org); Biotechnology for Latin America and the Caribbean (www.unu-biolac.com)

In the near future, it is expected that LAC will become a key players in the new concept for bio-economy. Alternative fuels from renewable cellulosic biomass (plant stalks, trunks, stems, agricultural waste, and leaves) have a tremendous potential to reduce LAC dependence on imported oil and decrease the environmental impact of energy use. Ethanol and other advanced biofuels from cellulosic biomass are renewable alternatives that could increase domestic production of transportation fuels, revitalize rural economies, and reduce carbon dioxide and pollutant emissions. This is contained within the technology of the bio-refinery whose objective is to convert the raw material into intermediate and finished useful products. A biorefinery can utilize different feed stocks of cellulosic biomass, can incorporate many different processes, and can result in many different end products and fuels. The exact configuration of a particular biorefinery will depend on market prices of inputs, demand for final products, access to the appropriate technologies, availability of financing, operational knowledge and supporting policies and institutions.

In this context, Latin America is actively seeking out, and seeking to apply the advancements made by U.S./Europe waste-to-energy companies in the last two decades. Waste-to-energy companies may be interested in new business opportunities for their systems in overseas markets. However, there are many obstacles to overcome in marketing technology and waste disposal services in developing countries. On the other hand, biomass conversion processes are becoming an important option in Latin America countries.

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ABBREVIATIONS AND ACRONYMS

AID	Agency for International Development
ASEAS	Asociación Colombiana de Entidades Administradoras de Aseo Urbano
BFD	Bubbling Fluidized Bed
BIOLAC	Latin American Biogas Network
BRC	Bioenergy Research Center
BUNCA	Central American Biogas Network
CDM	Clean Development mechanism
CDM EB	Clean Development mechanism-Executive Board
CEMPRE	Compromiso Empresarial para Reciclaje, Brasil
CEPIS	Centro Panamericano de Ingeniería Sanitaria y Ciencias del Ambiente
CER	Certified Emissions Reductions
CFB	Circulating Fluidized Bed
CH ₄	Methane
CO	Carbon Monoxide
CO ₂	Carbon dioxide
DBO	Design Build and Operate
DEFRA	Department for Environment, Food Rural Affairs
DOE	Department of Energy, USA
ECLAC	Economic Commission for Latin America and the Caribbean
EPA	Environmental Protection Agency
ESC AP	Economic and Social Commission for Asia and the Pacific
GHG	Green Housing Gas
GTZ	German Agency for Technical Cooperation
H ₂	Hydrogen
H ₂ S	Hydrogen Sulfide
HW	Hospital Waste
HW	Hazardous Waste
IBS	Integrated Biogas System
IDB	Inter American Development Bank
IEA	International Energy Agency
ISWA	International Solid Waste Association
IWSA	Integrated Waste Services Association
JICA	Japan International Cooperation Agency
LAC	Latin American and Caribbean Countries
LFG	Landfill Gas
MACT	Maximum Available Technology
MDG	Millennium Development Goals
MSW	Municipal Solid Waste
NGO	Non Government Organization
Nox	Nitrogen Oxide
O ₂	Oxygen

OECD	Organization for Economic Cooperation and Development
OLADE	Latin American Energy Organization
PAHO	Pan American Health Organization
R&D	Research and Development
RDF	Refuse Derived Fuel
	Reduced Emissions from Deforestation and Degradation in Developing
REED	Countries
REPAMA	Pan American Network for Environmental Waste Management
SVO	Straight Vegetable Oil
tonne	1000 Kg
TPES	Total Primary Energy Supply
UK	United Kingdom
UNDP	United Nations Development Programme
UNFCC	United Nations Framework Convention on Climate Change
UNIDO	United Nations Industrial Development Organization
US\$	United States Dollar
USAID	United States Agency for International Development
WB	World Bank
WHO	World Health Organization
WTE	Waste to Energy
WTERT	Waste to Energy Research and Technology Council
WTO	World Trade Organization

1. INTRODUCTION

At present, there is much interest in energy production from Municipal Solid Waste (MSW, waste that is produced in households). It generally comprises a mixture of organic matter (food wastes), plastics, paper, glass, metal and other inert parts. It can also include some commercial and industrial waste that is similar in nature to household waste. MSW is primarily considered a liability. It needs to be collected and processed, which comes at a certain cost. If managed improperly, it can cause severe human health problems and harm the environment. However, MSW also represents an opportunity, for example for recycling and re-use of materials in the waste stream, and for the production of energy. Energy from MSW is often seen as a great opportunity for developing countries to produce energy from a cheap and readily available resource. However, it also raises a few questions:

- What are the environmental impacts?
- Is energy produced from MSW renewable?
- Can MSW offer a significant contribution to the energy supply of developing countries?
- Are Latin American countries ready to apply this new technology?

Waste to Energy (WTE) is a general term to describe an incineration process which uses MSW as raw material. WTE industry is gaining growing acceptance worldwide as an important part of the waste treatment hierarchy- ‘reduce, reuse, recycle, recover and dispose’, with WTE being considered part of ‘recover’. However, it is only applicable when a number of overall criteria are fulfilled:

- Existence of a mature and well-functioning waste collection and management system for a number of years.
- A minimum and stable supply of combustible waste (at least 50,000 tons/year).
- A minimum average lower calorific value (at least 7 MJ/kg, never below 6 MJ/kg).
- A community that is willing to absorb the increased treatment cost.
- Skilled staff that can be recruited and maintained.
- Solid waste disposal at controlled and well-operated landfills.
- A stable planning environment for the community (planning horizon at least 15 years).

In Latin America and the Caribbean countries (LAC) is very difficult to fulfill these requirements. In fact, the management of solid wastes is complex and has evolved in parallel with the urbanization process, economic growth, and industrialization. To address this subject, it is not sufficient to know the technical aspects of collection, street sweeping and final disposal. It is also necessary to apply new concepts in finance, decentralization, private sector participation, health issues, environment, poverty in urban marginal settlements, education, and community participation. Therefore, the introduction and expansion of WTE programs becomes a real challenge in LAC. There are few pilot projects for big cities in Brazil, Mexico, Chile and Colombia. On the other hand, bioenergy by using biomass resources shows a major impact on research and real application in LAC.

A full review of broad and complex issues such as these is beyond the scope of this brief report; the focus here is on some of the key technology, policy and market issues related to the Waste to Energy industry in Latin America and its relation to energy and waste sectors. The examples used are intended to illustrate the way in which the bio-economy derives its value from a broad array of biomass resources,

including various agricultural and industrial residues, municipal waste, forest plantations, natural forests, and agricultural crops.

2. SOLID WASTE

2.1 WASTE MANAGEMENT STRATEGY

Climate change has already had a measurable impact on many natural and human systems. The effects are projected to increase in severity as the global average temperature rises. Although the evidence indicates that the time for global action is limited, it is generally believed that there is still time to avoid the most damaging impacts of climate change, if the global community takes decisive action now.

No single policy initiative or technology will achieve the GHG emission reductions required to achieve climate stabilisation. Rather, it will require a portfolio of mitigation solutions. The waste sector must be part of this portfolio, as it can deliver significant GHG savings.

The global direct GHG emissions resulting from waste management activities are around 1.3Gt CO₂ eq. or approximately 3 – 5% of total anthropogenic emissions in 2005 (IPPC, 2007). However, there is now credible evidence that, taking into account associated avoided emissions, the waste sector can completely change this picture.

On regional and city scales, the waste sector has the opportunity to change from a net emitter into a net reducer of GHG emissions. Through careful selection and use of existing waste management systems and technologies, many regions and cities can work to achieve an internationally significant reduction of GHG emissions.

Over the past several decades, there have been significant advances in the practices and technologies employed to collect, treat, recycle and recover waste. This progress has been aimed at improving public health conditions in local communities and cities and minimising the environmental impacts associated with managing waste.

As a result there are now a wide range of mature and environmentally effective waste management technologies in use which can also provide positive mitigation of GHG emissions. The selection of appropriate waste management options must be based on local conditions.

The choice is most frequently in the hands of local decision makers; however, consideration of the GHG impact of the available options is increasingly forming part of the selection process. Cities and local communities are including waste management solutions in their climate action plans. It's crucial that policy makers at national and international levels recognise these initiatives and promote the waste sector's mitigation potential, encouraging local solutions which help to address this global problem.

As waste management practices have evolved and awareness of the scarcity of natural resources has grown, there has been a paradigm shift from a waste management to a resource management philosophy. Through material and energy recovery, waste is increasingly considered as a resource to be exploited. These activities have an important potential for GHG emissions reduction. Waste can become an integrated part of the overall material flow through the economy.

Climate change should be viewed as an opportunity and not a risk for the waste management industry. The challenge of a new low-carbon economy is an effective innovation driver for waste management

activities. While there are already many proven technologies available which can make a significant contribution, the current push towards GHG reduction solutions can only result in more efficient waste management systems. By combining new and existing technical solutions, backed by industry experience, the waste industry can define a new framework for targets and objectives advancing future waste management policy and practice.

According to The International Solid Waste Association, there are three key components to a unified waste management strategy which would enable the waste sector to become a global net GHG emissions saver (ISWA, 2009):

1. Establish integrated waste management systems, with an emphasis on waste reduction and recycling to reduce the drain on material and energy resources,
2. Introduce waste technologies with lower energy consumption and re-use of processed residuals,
3. Recover energy from waste processing and captured landfill gas, for use as electricity or in heating and cooling systems, thereby replacing the use of fossil fuels for energy production.

Waste prevention, or waste avoidance, or zero waste, is the subject of new legislative initiatives, for example in the Netherlands and Scotland. It is also an area of current research, including natural, technical and social sciences as well as humanities publications in scientific literature. And it is a highly political issue, with many stakeholders contributing to a lively debate in the media.

There are many issues under discussion. At what point does the energy required to recover a material become too much to justify its reuse or recycling? To what extent do public health and services to citizens limit waste prevention? Waste prevention is an issue of high priority in waste management and it is likely that a number of new approaches will develop worldwide over the coming decades. The choice of waste process and technology will depend on local conditions and resources, as well as the composition of wastes from households, trade and industry. The potential for GHG emission reduction will vary accordingly. For instance, although developing countries produce waste containing a lower organic content per capita, the percentage of organic material is higher; this would impact on technology selection.

2.2 THE CURRENT STATE OF SOLID WASTE IN LATIN AMERICA

It is estimated that approximately 78% of the Region's population are urban dwellers. Small and medium-sized urban centers, which face the greatest difficulties in adequately managing solid waste, produce 44% of municipal solid waste (PAHO, 2007). Collection service in outlying areas - where the population is generally poor and access is hampered by inadequate road conditions and infrastructure - is not considered a high priority. The Region's solid waste sector and its institutional framework have differing degrees of development. Ministers of health and the environment provide oversight and regulate the sector, while municipalities maintain ownership of services provision. In general, deficiencies can be observed in sector management, as well as in medium- and long-term planning and programming. Municipalities typically lack management and economic capacity; notable omissions are seen in the legal framework; adequate control instruments to verify compliance and impose penalties are wanting; there is overlapping legislation—at times contradictory—and jurisdictional conflicts; and only a few countries have established specific laws dealing with solid waste.

Most countries do not have comprehensive solid waste management policies, and those that do often do not enforce or disseminate them. Few countries have comprehensive plans and strategic planning for the sector, and in many it is impossible to define a national lead agency for policy and plans. The few oversight responsibilities that are fulfilled are done so in a patchwork manner by the ministries of health and the environment. Municipalities set forth regulations for household, non-hazardous industrial, and hospital solid waste, and regulate rates with some executive control. The Region's average cost for solid waste services is US\$ 29 per ton, 70% of which corresponds to sweeping, collection, and transport. The rate, however, only covers 47% of service costs, and defaulted payments approach 50% (PAHO, 2007). Sector-wide investment is limited compared to that which is made in electricity, water, and sanitation. In most countries, the service is supported by collection of a municipal fee, but the fee is not only for the cleaning service; rather, it is part of street lighting, property taxes, and other taxes. It is estimated that only 22.6% of waste generated in the Region is deposited in a sanitary landfill; 23.7% ends up in controlled landfills, and 45.2% in open-air dumps or watercourses. Society's participation in solid waste management is limited and is only given effective expression when there is support from non-governmental organizations. The creation of microenterprises and cooperatives to manage solid waste is on the rise. These companies represent an economic municipal alternative, using low-cost technology and intensive labor, creating employment, and fostering community participation. Their participation in cleaning services is usually carried out with the support of non-governmental organizations. Solid waste management cooperatives, although not numerous, provide services for the poorest segments of the population.

2.3 DIAGNOSIS OF WASTE MANAGEMENT IN LATIN AMERICA

In the late 90's, The Inter-American Development Bank (IDB) and The Pan American Health Organization (PAHO) joined efforts to improve municipal and hazardous solid waste management, to extend service coverage, and to develop human and institutional resources. Therefore there was the first Diagnosis of municipal waste management in Latin America and the Caribbean (PAHO, Serie Ambiental, 1998). The Diagnosis has identified the following critical aspects and conclusions under six categories that still valid today: (1) institutional and legal area; (2) technical and operational area; (3) economic and financing area; (4) health area; (5) environmental area; and (6) social and community area.

Institutional and legal area

1.1 Institutional weakness. In the countries of the Region, the solid waste sector has not been formally recognized, thus, until now, its relevance and priorities have not received the attention it needs. The lack of a lead regulatory agency affects resource availability, information processes and service coverage. In the Caribbean, the institutional structure works better, partly, because of the size of the countries, which makes it possible to have a single governmental organization to conduct the sector.

1.2 Centralism and deficient operation. The role of the State as administrator, regulator and supervisor is deficient, as well as the role of local governments as operators. Limitations are due to centralism and lack of priority of solid waste management, despite the fact that many municipalities allocate almost half of their budget to urban cleaning.

1.3 Lack of planning. There are no long-term operational, financial or environmental plans with regard to solid waste management, either at national or executive agency level.

1.4 Lack of national information and monitoring systems. This restricts planning and program formulation, appropriate decision-making, adequate management, hierarchy of activities, resource allocation, and monitoring, surveillance, and control.

1.5 Inadequate legislation. There is no coherence among legal provisions relating to municipal, special, and hazardous solid wastes and the threat they pose to public health and the environment. Legislation is incomplete and ambiguous in respect of the scope of action of the administrative entities involved and is incompatible with economic, social, and cultural situations. In addition, there are too many complementary and administrative ordinances. Most countries fail to comply with the international commitments assumed by their governments.

1.6 Noncompliance with legal instruments. In some cases, legislation is unknown due to insufficient dissemination; in other cases there is advanced legislation but it is not enforced. In federal countries, there is not a regulatory formula to oblige municipalities to comply with certain federal environmental and financial standards.

1.7 Lack of policies to reduce solid waste generation. The official rhetoric still prevails as well as the promotion of environmentalist groups. Policies for recovery, reuse, and recycling of solid wastes have had a steady progress in the countries motivated by poor communities looking for income. Some countries have established policies based on the 'polluter pays' principle, however, they cannot be applied due to lack of resources.

1.8 Short, medium and long-term programs. Few countries have formulated them; some master plans for metropolitan areas and large cities have been prepared, but only few have been implemented. Most pilot projects have only academic and technical value but little remains, due mainly to lack of economic and financial self-sustainability. Microenterprises projects, however, are excepted and their progress in LAC is constant.

1.9 Human resources qualification. There is lack of trained and skilled human resources at all levels. Wages are low and at survival levels. Social and health benefits are few and do not exist for informal workers. Political interference is frequent and can involve hiring of excessive personnel and appointment of non-qualified executives. This situation is even more critical in medium and small size cities.

1.10 Privatization. The current trend is toward greater participation of the private sector in solid waste management. The general opinion is that the private sector is more efficient than the public sector and that it can also improve service quality and costs. Contracting and concessions to the private sector are alternatives for municipalities that lack resources for investments.

Technical and operational area

2.1 Management of especial and hazardous wastes. These are usually mixed with municipal solid wastes. The main cause of this problem is the lack of control due to insufficient human and financial resources; lack of sanctions for violators; and political favors, privileges, and corruption.

2.2 Temporary waste storage. Lack of standardization and poor maintenance of containers is rampant, and the use of containers in public areas convert them into dirty dumps with odor and vector proliferation.

2.3 Sweeping. Replacement of manual sweeping with mechanical sweeping is a dilemma for municipal authorities because manual operation takes up a high number of unskilled workers. On the other hand, the sweeping quality has been improved and its cost has been reduced with privatization.

2.4 Collection with equipment. Coverage higher than 90% has been achieved in numerous large cities of the Region. A critical aspect, however, is the low coverage in medium and small-size cities and the limited attention to urban marginal settlements.

2.5 Transfer stations. There are problems regarding its location and operation that can affect negatively the environment and life quality of nearby populations.

2.6 Incineration and composting. Incineration has been limited to hospitals and industries. As a result, critical aspects have not been identified. Most probably, Caribbean countries and some cities with specific problems will use it in the future. On the other hand, composting has presented critical problems due to lack of feasibility studies, including marketing and commercialization.

2.7 Final disposal. Governments, community, and the media have given priority to hospital solid waste management (600 t daily throughout the Region), however, the final disposal of 330,000 t daily of municipal waste that represent a potential hazard, has not received the same attention.

2.8 Sanitary landfill. It is the most common disposal method in LAC, although most of them do not fulfill the required technical specifications. The quality of few sanitary landfills has improved in recent years, although leaching is still not treated and synthetic membranes are not used for imperviousness. In medium and small-size cities, and even in some large ones, waste is disposed of in open dumps and water bodies. The construction of manual landfills is feasible as demonstration projects in very small urban nuclei; it is possible that microenterprises may be a viable alternative.

2.9 Equipment maintenance and facilities. It has been partly solved with the contracting out of maintenance service to private companies.

2.10 Recycling and reuse. It is practiced widely in LAC. In some cities, the recovered quantity has increased, scavenger groups have been organized, marketing of recovered material is more equitable and the number of recycling industries has also increased. However, the social problems of scavengers still prevail and no facilities have been devised for them to access financial credits.

Economic-financial area

3.1 Evaluation of economic benefits. Except for some countries in the Caribbean, the governments of the Region have not identified the economic benefits of adequate MSW and HW management. Since it is not possible to quantify them, evaluations are restricted to estimations of the value of recovered and recycled materials, sale of compost, gas methane or energy from incineration, increase of land value recovered by sanitary landfills, and other marginal benefits.

3.2 Sector financing. Most financial resources come from municipalities and limited national resources (federal or state). The interest of international and bilateral organizations is recent and usually financing is not exclusively for solid waste projects. Another problem is the poor access of intermediate and small municipalities to international and bilateral credit, and the lack of accounting information on solid waste management costs.

3.3 Cleaning rates and tariffs. Municipalities usually collect very low rates and tariffs due to political reasons, difficulty of collection, lack of community education or because the service is of such a poor quality that the users refuse to pay for it. This aspect is crucial to achieve self-financing in the countries of the Region.

3.4 Service collection. Collection is not efficient when included in the billing of real estate taxes or when it is collected directly at a specific rate, since the rate of delayed payments is very high. On the other hand, when it is invoiced with other public services, such as drinking water and electricity, it is usually efficient and self-financing is achieved. The problem appears when legal devices hinder this type of marketing or forbid the cutting-off of water or electricity when the service is not paid.

Health area

The population exposed to physical, chemical and biological agents of MSW are formal and informal workers who handle wastes; non-served population living near MSW treatment and disposal sites; scavengers and their families; and the population in general through surface and groundwater contamination, waste-fed animals, and exposure to hazardous waste. The main factors that contribute to this situation are the lack of concern of sector authorities and the poor quality of services.

Environmental area

Negative environmental impact is present in the following decreasing order of risk: final disposal sites; temporary storage sites; transfer stations, treatment and recovery plants; and during collection and transportation processes. The impact affects water, air, soil, and landscape. Compliance in environmental protection regulations has to face institutional, legal, financial, and especially surveillance limitations. On the other hand, policies to reduce the generation of municipal, special and hazardous wastes have not yielded results; and the reduction of hazardous wastes at the source, through cleaner production, is still an emerging practice. To achieve sustainable development, it is necessary to increase waste recovery, reuse, and recycling. The most important issue to prevent negative environmental impacts is to improve MSW management, specifically final disposal.

Social and community sector

Community participation in solid waste management is weak because it is considered as a responsibility of the municipalities; hence, the attitude toward service payment is negative. The education of the main players in the process, authorities, producers, and generators, and especially the community, is an important part of Agenda 21 postulates and although it is a long-term process, it is the correct way to achieve sustainable solid waste services. Achievements obtained in industrialized countries confirm it. Finally, while unemployment and extreme poverty continue, there will be solid waste scavengers. It is necessary to mitigate this social problem and to support the organization and development of managerial, operational and financing capabilities of cooperatives, associations and microenterprises of scavengers.

2.4 WASTE MANAGEMENT: POLICIES, PLANTS AND PROGRAMS

Policies

Most countries do not have specific national policies on waste problems and the few that have attempted to develop them, such as Brazil, Mexico, Costa Rica, Colombia, and Chile still need to overcome obstacles, restrictions and new queries. The decentralization policies in Latin America have not had a major influence on solid waste management since, constitutionally, these services have been, and are, administered in a decentralized way by municipalities.

The recent neoliberal policies are influencing and strengthening the privatization trend of solid waste management services initiated in the 1980s. Nevertheless, it should be noted that this policy is being applied mainly in metropolitan areas and large cities, and in a more restricted way in medium cities, with the participation of microbusinesses. In the countries of the Region, policies to reduce solid waste

generation have not been established formally. In spite of the official rhetoric and the promotion of environmentalist groups, results are still not evident. There has been sustained progress in the countries with regard to solid waste recovery, reuse and recycling practices, although in most of them official policies have not been established, but have arisen spontaneously several decades ago, within poor communities looking for income alternatives. In all countries, informal segregation is commonly practiced and frequently it is the only income source for large segments of the poor and unemployed population. In Colombia, Mexico, Brazil, and Venezuela large recycling programs are in progress. With regard to hazardous waste, produced mainly by industry, the principle "the polluter pays" has been established, although not explicitly, in several countries of the Region. It is difficult to apply due to lack of resources required to hire skilled personnel for control and surveillance and because there is not adequate technology and scientific instruments. In Mexico, the policies on sustainable development are considering solid and hazardous waste management. In Brazil there is a National Environmental Policy law and in Argentina, a law to define the environmental policy is being prepared. Other national policies and strategies, stated but not implemented, are: improvement of the coverage and quality of urban cleaning services; community education and participation in solid waste management; promotion of waste recovery at the source; technical assistance to municipalities; and sound hospital waste management.

Plans, programs and projects

In 1995 and 1996 the governments of Colombia, Guatemala, Mexico and Uruguay, with PAHO, IDB, IBRD and USAID support, carried out the solid waste sector analyses in those countries. It is expected that these studies, as has already happened, can be used as tools to prepare policies aimed at developing the sector, to identify and overcome critical aspects of collection and final disposal and in addition, to provide criteria for the adoption of strategies leading to viable solutions, in line with the possibilities and potential within the countries. ECLAC, with the collaboration and contribution of GTZ, from the German Republic, is implementing the project "Policies for environmentally sound management of urban and industrial solid waste." It has carried out studies in Brazil (Campinas), Chile, Ecuador (Quito), Colombia (Cartagena), and Argentina (Cordoba), it has offered courses and seminars, and has produced and disseminated several reports and documents. Moreover, with the support of GTZ, CEPIS is coordinating through REPAMAR, the development of projects on environmental management of hospital wastes: solid waste generation minimization, industrial pollution prevention; and technical cooperation between universities, among others, to be implemented in eight countries. Most countries identify as serious the problem of urban solid waste handled together with hazardous wastes, and consider that solutions should be sought immediately. However, this is not reflected in the few plans, programs, and projects in process. Master plans for metropolitan and large cities are in high demand but few have been implemented and, unfortunately, most solid waste management plans are improvised and influenced by occasional environmental policies. The Region has pilot waste management projects, some are academic and others are technical, but few survive more than a few years. The reason is that project design does not include monitoring or follow-up, nor the adoption of legal, institutional, administrative or self-sustainable economic and financing mechanisms. The exception is the creation of collection microbusinesses and cooperatives (especially, recycling) that 20 years ago did not exist. Although they currently need support to improve its managerial and operational capacity, they can be regarded as permanent and successful experiences. Some more recent projects financed by IDB, JICA, IBRD and other agencies that have used preinvestment loans to prepare master plans including strategic

planning concepts, such as financial sustainability and environmental impact, are also considered successful ventures.

Table 1. Plans, programs and project in LAC.

Plans, programs, projects	Countries	Cooperation and financing
1. National plans and programs for urban social waste management	<ul style="list-style-type: none"> •Bolivia (GARSU plan for nine large cities) •Mexico (solid waste pilot projects for 2 cities, 1990) •Mexico (solid waste projects for 25 cities implemented since 1995). •Colombia (Institutional Strengthening Program for Urban Environmental Management) •Honduras (National MSW Plan) •Paraguay (National Plan) •Costa Rica (National Waste Management Plan) 	JICA, IBRD IBRD IBRD IBRD IBRD GTZ
2. Metropolitan master plans	<ul style="list-style-type: none"> •Guatemala (Guatemala Metropolitan Area 1990-92) •Paraguay (Asuncion Metropolitan Area 1993) •Paraguay (Quindy, Paraguari, Vileta) •Bolivia (La Paz) •Chile (Regulation Plan of Santiago) 	JICA JICA JICA JICA, IBRD
3. Hazardous waste	<ul style="list-style-type: none"> •Brazil (Clean Industrial Protection Program PRONACOP) •Mexico (Environmental Program of the Northern Border) •Argentina (Hazardous Waste Management Plan for Buenos Aires) •Brazil (Solid Waste in Health Systems Campinas) •Peru (Hazardous Chemical Control) 	IBRD IBRD ECLAC-UNEP-GTZ ECLAC-UNEP-GTZ
4. Pilot projects	<ul style="list-style-type: none"> •Brazil (Integrated Management models) •Paraguay (Bioconversion and manual sanitary landfills in Carapegua) •Brazil (Integrated management models control and management for sanitation river Guarapilanga, Sao Paulo) •Colombia (Recycling cooperatives) •Mexico (Small recycling utilities, Mexico City) •Brazil (Recycling in Belo Horizonte and 	UNDP GTZ IBRD

	Puerto Alegre) •Colombia, Peru, Cuba (Women's proje •Honduras (Collection microbusiness) •Peru (Solid waste management on semi urban areas)	Local NGO Local NGO USAID
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Source: PAHO, Sectorial studies on solid waste 1995/97. Reports ECLAC, GTZ

3. ENERGY IN LATIN AMERICA

3.1 ENERGY POVERTY

New technology together with new laws and regulations has promoted changes in energy sectors, especially in getting renewable sources. However there is not much ongoing collaboration in the area of energy poverty. Expanding access to modern energy services (household access to electricity and clean cooking facilities: clean cooking fuels and stoves, advances biomass cooking stoves and biogas systems) will require participation from many others players, at the regional, national and local levels, the international community and the private sector. It is an alarming fact that today billions of people lack access to the most basic energy services, electricity and cooking facilities, and worse, this situation is likely to change very little over the next 20 years, especially in LAC.

According to International Energy Agency (IEA) there are around 1.4 billion people (over 20% of global population) that do not have access to electricity and that 2.7 billion people (around 40% of the global population) rely on the traditional use of biomass for cooking. IEA projections suggest that the problem will persist and even deepen in the longer term: 1.2 billion people still lack access to electricity in 2030, 87% living in rural areas. Most of these people will be living in Sub-Saharan Africa, India and other developing Asian countries (excluding China). In the same projection, the number of people relying on the traditional use of biomass for cooking rises to 2.8 billions in 2030 (82% of them in rural areas).

Table 2. Number of people without access to electricity and relying on the traditional use of biomass, 2009 (Million)

Region	Number of people lacking access to electricity	Number of people relying on the traditional use of biomass for cooking
Africa	587	657
Sub- Saharan Africa	585	653
Developing Asia	799	1937
China	8	423
India	404	855
Other Asia	387	659
Latin America	31	85
Developing countries*	1438	2679
World**	1441	2679

*Includes Middle East Countries. **Includes OECD and transitions economies.

Source: IEA, Databases and analysis, 2009.

3.2 ENERGY AND DEVELOPMENT

Access to modern forms of energy is essential for the provision of clean water, sanitation and healthcare and provides great benefits to development through the provision of reliable and efficient lighting, heating, cooking, mechanical power, and transport and telecommunication services. The international community has been aware of the close correlation between income levels and access to modern energy: not surprisingly, countries with a large proportion of population living on an income less than \$2 per day tend to have low electrification rates and high proportion of the population relying on traditional biomass. As incomes increase, access to electricity rises at a faster rate than access to modern cooking fuels, largely because governments give higher priority to electrification, although access to both electricity and clean cooking facilities is essential for success in eradicating the worst effects of poverty and in putting poor communities on the path of development.

The adverse consequences of the use of traditional forms of energy for health, economic development and the environment are well illustrated by the example of the use of traditional biomass for cooking. Currently, devices for cooking with biomass are mostly three-stone fires, traditional mud stoves or metal, cement and pottery or brick stoves, with no chimneys or hoods. As consequence of the pollutants emitted by these devices, pollution levels inside households cooking with biomass are often many times higher than typical outdoor levels, even those in highly polluted cities. The WHO estimates that more than 1.45 million people die prematurely each year from household air pollution due to inefficient biomass combustion. A significant proportion of these are young children, who spend hours each day breathing smoke pollution from cook stove. Today, the number of premature deaths from household's air pollution is greater than the number of premature deaths from malaria or tuberculosis (Mathers & Loncar, 2006).

In LAC in which households are heavily reliant on biomass, women and children are generally responsible for fuel collection (a time consuming and exhausting task). Women can suffer serious long term physical damage from strenuous work without sufficient recuperation. This risk, as well as the hazards of falls, insect bites or human assault, rise steeply the further from home women have to walk. Inefficient and unsustainable cooking practices also have serious implications for the environment, such as land degradation and local and regional air pollution. In cities where households are primarily reliant on wood or wood-based charcoal, there is a local deforestation in the surrounding areas.

Effective environmental management cannot be excluded from energy and development concerns. Preventing irreversible damage to the global climate will require decarbonisation of the world's energy system. For LAC however, difficult choices have to be made in allocating scarce resources among pressing development needs and climate change is often viewed as a longer-term concern that must be traded off against short-term priorities. While the poorest developing countries are not major contributors to climate change, their populations suffer acutely from its effects. For net oil importing developing countries in particular, rising and volatile prices have amplified the challenge of expanding energy access and put extra burden on fiscal budgets. In high energy price and climate-conscious world, it makes sense for governments tackling the energy poverty challenge to choose a mix of technologies used by developed countries. Then WTE needs to be evaluated for its potential to become a sustainable option for modern energy services in poor rural areas of Latin America.

3.3 BIOGAS

Biogas originates from bacteria during the process of bio-degradation of organic materials under anaerobic (without air) conditions. The natural generation of biogas is an important part of the

biogeochemical carbon cycle. Methanogens (methane-producing bacteria) are the last link in the chain of micro-organisms that degrade organic materials and return the decomposed products to the environment. It is in this step of the biogeochemical carbon cycle that biogas, a source of renewable energy, is generated.

Knowledge of the fundamental processes involved in methane fermentation is necessary for planning, building and operating biogas plants. Anaerobic fermentation involves the activities of three different bacterial communities. Biogas production also depends on certain specific conditions. For example, changes in ambient temperature can have a negative effect on bacterial activity.

Biogas has proven its viability as an energy technology in rural areas of Asia, in particular, India, Nepal, Bangladesh, and China. Over the past 25 years, different types of biogas digesters have been developed and their installation has been commercialized. Technical assistance agencies, bilateral donors and multilateral financing institutions have supported the promotion of biogas technology and assisted the private sector with manufacturing and dissemination of the proper technology. In 2005, the World Bank signed a Memorandum of Understanding that facilitates the trade in emission rights from biogas technology. Biogas projects in Brazil and Chile already apply CDM. Nepal recently signed the Kyoto Protocol in 2005 and biogas programmes are in place which will benefit from the sale of Certified Emission Reductions (CERs) by Nepal (ESCAP, 2007). Under a proper policy regime, the income from the sale of CERs can be used to reduce investment costs in biogas equipment. This will accelerate the purchase of biogas digesters by private households and investments in large biogas plants by commercial enterprises, which will further reduce pollution and provide alternative source of affordable energy.

Biology of Methanogenesis

In general, all organic materials can ferment or be digested. However, only homogenous and liquid substrates can be considered for simple biogas plants: faeces and urine from cattle, pigs and possibly poultry, as well as wastewater from toilets. When the plant is at capacity, the excrement is diluted with an equal quantity of liquid, such as urine if available. Waste and wastewater from food-processing industries are only suitable for simple plants if they are homogenous and in liquid forms. The maximum gas-production from a given amount of raw material depends on the type of substrate.

Composition and Properties of Biogas

Biogas is a mixture of gases mainly composed of:

- Methane (CH_4): 40-70 % by volume
- Carbon dioxide (CO_2): 30-60 % by volume
- Other gases: 1-5 % by volume, including: Hydrogen (H_2): 0-1 % by volume Hydrogen sulfide (H_2S): 0-3 % by volume. Like any pure gas, the properties of biogas are pressure- and temperature-dependent. They are also affected by the moisture content and other major factors such as:

Changes in volume as a function of temperature and pressure

Changes in calorific value as a function of temperature, pressure and water-vapor content

Changes in water-vapor content as a function of temperature and pressure

- The calorific power of biogas is about 6 kWh/m³ - this corresponds to about half a litre of diesel oil. The net calorific value depends on the efficiency of the burners or appliances. Methane is the most valuable component if the biogas is to be used as a fuel.

3.4 BIOGAS DEVELOPMENT PROGRAMMES FOR HOUSEHOLDS

The biogas has greatly promoted ecological agriculture and the environment. Biogas projects aim at providing a complete set of equipment that can turn organic wastes into clean biogas and efficient fertiliser by anaerobic processes. The equipment may be a simple device for family use or a large-size plant to treat agricultural waste. It can provide clean energy for everyday life, produce forage and fertiliser for agriculture, soak seeds, control insect and pest populations, increase output of plants and fruits, and improve the soil. With the popularization of biogas technology, the hygiene of the pigsty and toilet has been notably improved and the breeding of mosquitoes, flies and harmful germs prevented. As a result, the development of biogas has benefited the environment, the standard of living and economic development. It has brought about great changes in LAC rural areas. During the past years of biogas development, different models have emerged in different areas of LAC according to the needs of the local population.

Currently, there are over ten million low-cost digesters in India and China alone. In Costa Rica, there are approximately 1,500 low-cost digesters treating agricultural and human waste (Botero, 2010). While low-cost digestion systems are widespread, there has been a paucity of research regarding digester performance. Research and development in digestion technology in the United States and Europe has focused on large-scale, capital-intensive systems, which are appropriate for industrial-scale farms, but with an average cost of \$1.0 million are largely inaccessible to the medium and small-scale farmer. In Taiwanese-model, low-cost digesters wastewater flows through a tubular polyethylene or PVC bag, producing biogas with 60 – 70 % methane that can be used directly as a heat source, eliminating the need to burn wood or buy natural gas for cooking or heating. At an additional cost, an electrical generator can be used to produce electricity using the produced biogas. The construction, materials, and labor costs of an 8-meter long (25 m³) Taiwanese-model digester is approximately \$500 in Costa Rica, without electricity generation. A 25 m³ digester can treat waste from 55 pigs (50 kg), offering up to 6 m³ of biogas per day, with a methane content above 60%. Low-cost digesters are often plug-flow, the contents are not mixed and internal heating is not required when located in a tropical climate (Botero, 2010). The friction from digester walls and the effects of gas production do result in some mixing of the contents in small-scale digesters. The solids tend to settle out, resulting in a longer retention time than the liquid-portion of the wastewater and better degradation of solids in these systems compared to completely mixed reactors. Biogas from small-scale digesters can be used for electricity generation, but research on electricity production has been primarily confined to industrialized digesters. In the U.S., approximately 100 agricultural digesters are producing electricity (USEPA, 2006). The large amount of waste produced at these operations assures that enough methane for electricity generation is produced. Small farmers often lack the capacity to utilize these high-tech digesters. Preliminary studies indicate that large wastewater inputs and high capital costs are not necessary. The need to control odor and water pollution from animal facilities and a growing concern about global warming has led to more interest in biogas systems, but robust quantification and optimization studies for low-cost systems are lacking. However, biogas production (quantity and quality), and wastewater transformations in a digestion system that combines biogas from a swine digester and a dairy digester, is becoming a source of cheap

fuel at household level in Latin America. In fact there few regional programs working on biodigester as energy option: Latin American Biogas network [www. Red Biolac.org](http://www.RedBiolac.org); Biomass Users Network (www.bun-ca.org); Biotechnology for Latin America and the Caribbean (www.unu-biolac.com).

3.5 POTENTIALS AND CONSTRAINTS OF INTEGRATED BIOGAS SYSTEMS

In spite of the multitude of socio-economic and environmental benefits offered by the Integrated Biogas Systems (IBS) , their scaling-up as an intervention for sustainable livelihood and poverty alleviation programmes around the world has been rather disappointing, with the exception of a few East Asian countries (China, India, Bangladesh and Nepal). Barriers to the “mainstreaming” of the pilot biogas projects have been associated with the lack of an institutional enabling-policy framework, as well as technical and human capacity. In LAC there are diverse NGO’s working in rural areas, however, except for some South and Central American, many small- and large-scale biogas projects have not yet been able to move beyond the pilot phase. The barriers to their scaling-up and “mainstreaming” have been recognized as the following (ESCAP, 2007).

Technical (Biogas and Animal Husbandry) Competence

Lack of competent technicians and funds to mend repairs;
Poor material quality leading to corrosion, breakdown and leakages;
Lack of equipment supplies and spare parts;
Insufficient and poor quality feedstock for the digester and low temperature leading to low biogas yield;
Poor animal husbandry due to poor feed-quality and animal health and high emission of enteric methane.

Institutional and Policy Barriers

Sectoral, top-down, compartmentalized-approach in the delivery mechanism leading to lack of follow-up support services and ownership of projects;
Lack of governmental, institutional and local programmes focusing on “technology fix” (like the Integrated Biogas System);
Lack of sound fiscal policy to provide incentives (taxation, capital allowance) to attract investment in biogas technology.

Barriers to Social and Entrepreneurship Development

Lack of public awareness and gender-bias against women and marginalized groups of participants;
Lack of success with the entrepreneurial business model for scaling-up biogas system;
Cultural taboos preventing the use of animals and humans as feedstock for clean biogas and fertiliser;
Incorrectly placing the primary focus on dissemination rather than a commercialization modality for the “mainstream”;
Failed breeds and disappointment with loss of technology.
Barriers to Financing
Lack of access to affordable credits due to continual under-funding within the agricultural sector;
Failure to pay back loans due to underemployment;

Lack of a creative financial modality for the mainstreaming of the pilot biogas project (pros and cons of term loan, leasing and equity financing).

3.6 THE IMPORTANCE OF MODERN ENERGY IN ACHIEVING THE MDG'S

Goal 1. Eradicate extreme poverty and hunger: Access to modern energy facilitates economic development by providing more efficient and healthier means to undertake basic household tasks, and provides the means to undertake productive activities more generally, often more cheaply than by using the inefficient substitutes, such as candles and batteries. Modern energy can power water pumping, provide drinking water and increase agricultural yields through the use of machinery and irrigation.

Goal 2. Achieve universal primary education. In impoverished communities children commonly spend significant time gathering fuel wood, fetching water and cooking. Access to improved cooking fuels or technologies facilitates school attendance. Electricity is important for education because it facilitates communication, particularly through information technology, but also by the provision of such basic needs as lighting.

Goal 3. Promote gender equality and empower women. Improved access to electricity and modern fuels reduces the physical burden associated with carrying wood and frees up valuable time, especially for women, widening their employment opportunities. In addition, street lighting improves the safety of women and girls at night, allowing them to attend night schools and participate in community activities.

Goal 4, 5, and 6. Reduce child mortality; improve maternal health; and combat HIV/AIDS, malaria and other diseases. Most staple food require cooking and reducing household air pollution through improved cooking fuels and stoves decreases the risk of respiratory infections, chronic obstructive lung disease and lung cancer (especially when coal is used). Improved access to energy allows households to boil water, thus reducing the incidence of waterborne diseases. Improved access advances communication and transport services which are critical for emergency health care. Electricity and modern energy services support the functioning of health clinics and hospitals.

Goal 7. Ensure environmental sustainability. Modern cooking fuels and more efficient cook stoves can relieve pressures on the environment caused by the unsustainable use of biomass. The promotion of low-carbon renewable energy is congruent with the protection of the environment locally and globally, whereas the unsustainable exploitation of fuel wood causes local deforestation, soil degradation and erosion. Using cleaner energy also reduces greenhouse gas emissions and global warming.

Goal 8. Develop a global partnership for development. Electricity is necessary to power information and communications technology applications.

Source: Adapted from UN-Energy, 2005.

3.7 THE CURRENT STATE OF RENEWABLE IN LATIN AMERICA

According to recent data from the International Energy Agency (IEA), renewable energies amount to almost 29% of the total primary energy supply (TPES) in Latin America. At first, this figure looks relatively high and somewhat impressive, especially if we compare it to the 5.7% share of renewable of Organization for Economic Co-operation and Development (OECD) countries and the 0.7% share in the Middle East (GENI, 2009). These numbers, however, can be very misleading. In reality the situation of renewable energies in Latin America is not as positive or optimistic as we might want to think, or as certain statistical data lead us to believe. There are many problems associated with the implementation of renewables as well as their impact on the environment and society. In this context, the main problem for renewable energies in Latin America is in the way energy and development policies have been

constructed. In most cases, energy policies and strategies in Latin America have excluded renewables and other alternatives as being too costly and technologically unfeasible, or by arguing that the country does not have the capabilities to implement them. The easiest explanation for this, and one which is usually mentioned, is the lack of incentive and foresight. Since the region has an abundance of resources such as oil, gas, and hydro, it is in general easier, cheaper and more technically feasible to keep exploiting conventional energy resources than to invest in renewable energies or create appropriate renewable energy policies. Another common explanation is that the development of renewable energies clashes with the interests of powerful players, particularly large energy companies, and, therefore, there are few incentives to promote them. The Latin American renewable energy sector is almost entirely dominated by only two forms of renewable: hydro and biofuels, which make up respectively 36% and 62% share of the total of renewables. Other forms of renewable energies represent only an insignificant fraction of total energy production (1.4%) (GENI, 2009). The problem itself is that these two forms of energy are not in all cases the most adequate and in fact questionable to the extent of being renewable and sustainable. First of all, the hydroelectricity sector has been dominated by large hydro plants which produce almost the entire share of renewable energy to produce electricity. Large hydro plants have been constructed in Latin America for several decades now, as countries have embraced and promoted them as a means of reducing dependency on fossil fuels, especially given the large hydro potential of the region. Hydro plants have been particularly important in the production of electricity, as it represents 60% of total electrical production in Latin America. In countries like Brazil, Paraguay, and almost all Central American nations, this figure rises to more than 90% of the total. Hence, several Latin American countries have come to depend almost completely on the hydro sector for electricity. This has created problems for them on several occasions; particularly when there are extended dry periods and water levels fall significantly. Moreover, apart from creating energy security concerns, large hydro has caused serious environmental and social problems, particularly in sensitive regions like the Amazon rainforest. The construction, for example, of the Tucuruí hydro plant in the Brazilian rainforest flooded around 2400 square kilometers of rainforest and displaced around 30,000 indigenous people from their traditional territories. In this context, large hydro cannot be properly considered a form of clean, sustainable energy, particularly if viewed in the context of sustainable development.

In the case of biofuel, its percentage share among renewables has been decreasing considerably at the regional level for the simple reason that statistical data does not distinguish between traditional and industrial/modern biofuels. Traditional biofuels are those associated with subsistence energy consumption (firewood, grass), whereas industrial/modern forms concern mainly the production of biofuels such as ethanol and sugarcane. Since the 1970's, traditional biomass has decreased from 30% of total TPES to currently 15%, whereas modern biofuels have only increased slightly. Thus, as there is more urbanization and expansion of the electric grid, the percentage of biomass will keep shrinking as people turn from traditional biofuels to other sources of energy. Also, both traditional and industrial biofuels have come under heavy criticism from a number of NGO's, civil groups and certain government authorities for a number of reasons. The most common concern is that industrial biofuels do not contribute to reducing greenhouse gases, and they provoke a series of environmental and social problems, whereas traditional biofuels can lead to deforestation and other unsustainable practices. Although it is debatable to what extent these criticisms are true, it is clear that biofuels are not seen as the optimal solution by some, and that they can, as can big hydro, have negative consequences. Altogether, then, it is clear that the current situation of renewables in Latin America is worse than it appears at first sight. In fact, if we were to take away large hydro and unsustainable biofuels production, the region will not be much better than other parts of the world

3.8 POTENTIAL OF RENEWABLE ENERGIES IN LATIN AMERICA

All countries in the region are endowed with abundant renewable energy sources. Solar, wind, biomass, small hydro and other energy resources from the ocean are available in the region in larger or smaller quantities, depending on the geographical location and topography of the individual countries. The force of wind can be used to produce mechanical power and electricity by means of commercially available and cost-competitive technologies. Southeast Mexico and most Central American and Caribbean countries are subject to the influence of the Trade Winds, while Southern Mexico and Central America are exposed to strong and almost constant thermally driven winds, which in the case of Mexico are known as *Tehuantepecer*, produced by the temperature difference between the waters of the Atlantic and the Pacific oceans. Windy places can also be found in the southern hemisphere. Low winds cannot be effectively used to produce power while excessively strong winds may cause damage to wind generators. However, when properly located and sized, wind has proven to be a reliable energy resource. A few countries (basically Brazil and Argentina) in the Latin American region have developed wind maps to guide project developers. A low resolution wind map of the region was developed over a decade ago by the Latin American Energy Organization (OLADE). Solar energy is more evenly distributed, as good portions of the region lie within the Sun Belt Region of highest solar radiation. Thus, except for site specific adverse microclimates, solar energy is a predictable and reliable resource, capable of being transformed to heat and electricity by means of several technologies in different stages of development and is commercially available. Solar irradiance maps are available for Mexico, Colombia, Brazil, Argentina and a few other countries. As a natural consequence of the solar radiation available, photosynthetic activity in most of the region of study is rather high, and hence the high production of biomass fuels. In addition, many countries in the region have an economy based on agriculture, so that agricultural waste, forest residues and other residues from raising animals (e.g. manure or methane from decomposing waste) is also abundant. These resources are difficult to evaluate, so that information in a complete and analyzed form is difficult to find. Most countries in the region already use a good proportion of their hydraulic potential to generate electricity. Most operations are in the multi-megawatt range, seeking economies of scale characteristic of large hydroelectric technologies. This practice has left a large part of the small hydroelectric potential yet to be exploited. Given the high rainfall indices and the rough topography of many countries, small hydropower offers a good alternative to supply electricity, especially in remote sites. Wave and tidal power, along with other forms of energy available in the ocean, represent an enormous energy potential for coastal countries in the region, especially when one considers the large coastline-to-inland ratio of most countries in Latin America. Unfortunately, technologies to tap such energy resources are still far from commercialization.

The challenge of renewable energy resource development in the region is the fact that little has been done to properly measure and characterize these resources. In the case of project development, available information on the local renewable resource is often limited, if not unreliable. In most cases, information is non-existent, which represents a major barrier to the incorporation of this alternative as part of the national energy inventories and planning exercises. (IEA, 2011)

4. PROCESSING TECHNIQUES

4.1 RECYCLING

In the countries of the Region, poor people recover secondary materials from municipal solid waste as an income source. Barterers that buy or exchange used materials; garbage collectors that separate wastes during their route; scavengers that separate wastes in landfills, and people who buy wastes from offices (paper), restaurants (to feed animals), industries, etc., all of them are part of the recycling system. Recycling is widely practiced in LAC countries. Compared with developed countries, recovery and recycling is different due to the low content of recyclable materials produced by households. An important factor is the market for recovered material because if in the surrounding areas there are no factories to reprocess them, recycling will be limited to reuse or sale to intermediaries who trade them in more remote processor plants. The decisive factor is extreme poverty that makes it necessary to become informal scavengers to survive. It is estimated that the number of scavengers in the Region surpass one hundred thousand families involved in solid waste recovery. The degree of recycling in the countries is not known but, in general terms, it is not very great compared to the quantity of waste generated. Recycling is achieved in two ways, the first is through separation and collection in industries, businesses and large generators of homogeneous recyclable materials (paper, cardboard, bottles, plastics and ferrous and non-ferrous metals) to sell them to specialized private collectors. Usually, this type of recycling is profitable and environmentally positive because it can be carried out under conditions that protect the worker's health. These types of recycling programs, especially glass, have achieved great success in Colombia, Mexico, and Venezuela. The Federal District of Mexico has three municipal waste separation plants with a capacity of 1,500 t/day each one, recovering 10 to 15 % of the material, as reported by the Federal District Department (PAHO, Serie Ambiental, 1998). The second type of segregation is practiced on the refuse itself and consists of three possible interventions: first, by scavengers that pick up recyclable items in bags or containers; second, by garbage collectors in the collection truck; and third, by scavengers in the landfill. Obviously, this form of recovery is not recommended since it usually endangers the health of the segregators, causes aesthetic problems in the city, and inefficiencies in the municipal services. In general, the main beneficiaries are the intermediaries and the leaders of segregators and unions. In a recent study covering seven cities of Mexico it was found that the quantities recycled by these three types of intervention was less than 2% of all the refuse in weight. One of the problems of waste recovery is the diversion of collection trucks from their routes to discharge and sell wastes to recyclers, which increases collection costs. Another problem is pig feeding with wastes, which is critical for public health when pig breeders build their corrals within or near the dumps. A study carried out in Lima by DESCO in 1994 revealed that around 800 t/day were used to feed pigs in clandestine sites that provide up to 50% of the daily pork consumption (CEPIS, 1996). The most common recycling method in developed countries is the separation of recyclables in every household through community participation campaigns. In countries with active participation of the civil society and high educational level, results have been positive although some critics state that the real cost of the recovered material is high and that recycling companies pay subsidized prices. In countries of LAC, this method is applied partially only in some cities of Argentina, Colombia, Brazil and Mexico. The difference is due to unemployment and poverty, which favor the existence of scavengers, a social group that does not exist in developed countries where separation is done directly by the community at the source. In metropolitan Lima it is estimated that almost 5,000 people are involved in informal segregation, recovering 290 t daily (7 % of the total generated) that are taken to 350 retail deposits and 28 wholesale deposits where they are traded to 1,500 recycling companies, mainly small industries. In Colombia, with the support of NGOs, scavengers groups have been transformed into cooperatives or private formal associations that are achieving a successful operational

management. For example in Cali, the Precooperativa Socios Unidos is in charge of classifying and trading the material separated previously at the source. Source separation is only partial, since in spite of public campaigns, non-recyclable material is also included. Three out of seven tons collected daily are not recyclable. This program recycles between 40 and 60 t per month. Other groups of scavengers in Cali recycle 250 t weekly. In total, it is estimated that approximately 50 t are recovered per day, which only means less than 4% of the refuse generated daily in the city. Colombia is possibly the most advanced country in the organization and promotion of scavengers. In many cities, pre-cooperatives of scavengers have been established supported by non governmental and also governmental organizations for sanitary recovery, installation of centers to collect recovered materials, and fair trading with the recycling industry. The pre-cooperatives of Barranquilla are building seven collection centers; in Manizales, the main pre-cooperative has built a plant to recover 20 t/day, 10% of the total generated in the city at a cost of 1.2 million dollars; the two main pre-cooperatives of Popayán have collection centers and another new cooperative is developing a worm breeding project using organic matter from sanitary landfill. Recovery of materials separated at the source was also successful in some cities of Brazil since there were no cooperatives for this recovery and, on the other hand, the municipal support for these programs obtained profits, such as longer life of the sanitary landfill, lower collection costs, lower consumption of natural resources, and improvements in public health and the environment. In Rio de Janeiro, there are 16 cooperatives with 1,300 workers that separate 1,800 t per month (less than 1% of the MSW generated), which makes possible to obtain monthly salaries over the minimum wage. In Sao Paulo, the NGO CEMPRE, Compromiso Empresarial para Reciclagem, promotes recycling with an integrated management approach and jointly with the Instituto de Pesquisa Tecnológica (Institute of Technological Investigation) of Sao Paulo, it has published a manual on integrated waste management. Waste recovery with previous separation in households was also applied in Buenos Aires and remains, but subsidized. In Venezuela there are 199 recovery and recycling centers that cover 75 % of the material recovered in the country, but include only large waste generators.

In summary, solid waste recovery by segregation is not high in respect of the generated quantity, but for thousands of families it represents their only means of survival. The quantity of recovered material is larger when industries and large waste generators participate and the recycling industry promotes the process. Interesting results have been obtained in Colombia and other countries where large quantities of the following waste are recycled under this modality (PAHO, Serie Ambiental No.15, 1995):

- Glasses: in 1994, the two main glass industries in Colombia recycled 142,000 t and paid US\$ 62 per ton. In Venezuela, 20% of the glass is recycled. In Peru, 25 t/day is recovered. Mexico has also a large program.
- Metals: the semi-integrated steel industries of Colombia purchase annually 220,000 t of recovered scrap metal. In Brazil, in 1995, 18 % of ferrous metal packing was recovered and it is expected to reach 50% in two years; with regard to aluminum containers, 50% was recycled. In Venezuela, 78% of the aluminum is recycled.
- Paper and cardboard: these materials represent the highest volume of recyclables in Colombia, particularly from domestic and commercial origin. According to the Chamber of Pulp, Paper, and Cardboard, ANDI, in 1998, 49% (311.2 thousand tons) of the total of paper and cardboard came from recycled material and 80% was recovered by segregation. The price is between 120 and 140 dollars per ton. In Brazil, approximately 1.5 million tons of paper were recovered for recycling in 1998. In Venezuela, 55 % of paper was recycled in 1994. In Peru, 9,500 t/year are recovered. In Chile, 200,000 t/year are recovered, which represents 33 % of what is recoverable (PAHO, Serie Ambiental, 1998).
- Plastic: plastic recovery is done despite the highly polluting characteristics of the process, especially in small plants that do not meet environmental protection standards and requirements. In Brazil, only two

recycling plastic industries, of the various existing, use 1,000 t/month of recycled material. In Chile, plastic recovery reaches 23,000 annual tons (7 % of what is recoverable), which constitute 10 % of the annual plastic demand. In Uruguay, plastic was recovered but there was no market for it. In the Caribbean countries, solid waste recovery is not frequent because there are no recycling plants since the market in each island is small and most of the consumption items are imported; thus, solid waste final disposal and packing must be done in the country, without possibilities of recovery. However, there are exceptions, as in Trinidad and Tobago, where there is a glass factory that recycles 20% (4,400 t annually) of the total of collected glass; on the other hand, in that country 2,400 t of paper are recovered (5 % of the total of paper discarded annually) and are traded with Venezuela.

4.2 TREATMENT, INCINERATION AND BIOCONVERSION

Due to lack of land, high costs or to strict environmental legislation, many developed countries have adopted incineration and composting as treatment processes that can become partially competitive even when an advanced technology is used. These processes, which take advantage of refuse characteristics, gave place to projects on incineration with use of energy, bioconversion through compost, production of auxiliary fuel or RDF (refuse derived fuel) and biogas from sanitary landfills (in Santiago, Chile, for residential use and in Rio de Janeiro for COMLURB vehicles). These technologies have been adopted by several LAC cities, with discouraging results in most cases, except for some biogas recovery projects, due to lack of technical, institutional and economic analyses to justify investment. Currently, only in some LAC cities and under some very special circumstances, incineration and composting technologies would be justified. According to PAHO, these treatments cost 20 times more than sanitary landfills. Accordingly, incineration is restricted to small incinerators for special wastes, mainly in hospitals, ports, airports and industries, except for the city of Sao Paulo where the municipality is enclosed by other municipalities of the metropolitan area. There are incineration composting and recycling plants, each plant with a capacity of 2,500 tons per day. Each plant will burn 1,250 tons per day or will compost other 1,250 daily tons. The cost of the project is US\$ 600 million and should be financed by the private sector. A 20 year concession will be given and the Municipality of Sao Paulo will pay US\$ 70 per ton treated during the first 3 years and US\$ 25 per ton from the fourth year onward. The bidding was carried out 2 years ago but the project has not been implemented yet because there have been problems with one of the bidding consortia. In the city of Mexico, the municipal incinerator was closed in 1992 because it did not meet emission standards. The incinerator of the city of Buenos Aires is not working either. In Santiago, Chile, an attempt to install an incinerator was rejected because it was not economically viable. It has been reported that in Barbados, the government had to pay the loan for a small incinerator (a ton per day) that was granted to a private company. Up to 2000, no private company has invested or operated a large municipal incinerator in the Region. On the other hand, use of old incinerators in several cities has been forbidden, to avoid air pollution. Since the potential emission of dioxins and furanes, among other pollutants, poses a high health risk, the installation of low capacity incinerators has not yet been authorized in the Federal District, Corregidora (Querétaro) and other cities of Mexico. Incineration plants with energy recovery have recently been offered to various municipalities, although the economical and technical feasibility of those investments has not been confirmed. The production of compost through simplified processes, such as piling, rotary biodigestors and recently, worm breeding, is also being abandoned due to cost and because promoters promised profits to municipal authorities, when it has been verified that the use of the more environmentally acceptable alternatives has a cost. It is estimated that in the last 20 years no less than 30 compost plants have been purchased in the Region,

some never were installed and the machinery was abandoned; another 15 have closed after few years because the municipalities did not continue the subsidy. Lack of feasibility studies and reduced local market to trade derived products has been the main cause of the failure of these installations. Even though they were environmentally acceptable, municipalities could not continue subsidizing the high operational costs of the plants, especially if they had less expensive final disposal alternatives. Table 3.2.11 presents some data on the worldwide treatment and final disposal trends. The program for recovery and use of biogas produced in sanitary landfills deserves special attention. Monthly, in the city of Santiago, Chile, an average of 4 million cubic meters of biogas is recovered with a calorific power of more than 5,000 kcal/m³. This biogas is mixed with oil gas and distributed to the city through a pipe network for domestic consumption covering 40% of the total demand for this type of fuel. The sale price of the biogas to the gas company is US\$ 1.25 per million Kcals. Biogas recovery is similar in the city of Valparaíso. In a survey carried out in Brazil it was confirmed that 41 large and medium recycling and composting plants and 13 incinerators were in operation.

Table 3. Worldwide trend for treatment and final disposal

Country or region	Sanitary landfill	Combustion	Compost
United States	80	19	1
Japan	30	70	2
Germany	70	30	3
France	55	40	9
Switzerland	20	80	
Sweden	40	55	5
Spain	80	15	5
Latin America	98	1	1

Source: PAHO. El manejo de residuos sólidos municipales en América Latina y el Caribe. 1995. Serie Ambiental N° 15.

There is little information on compost plants in Latin America, but the following is available:

Table 4. Compost plants in LAC

Country or región	Description
Acapulco, Mexico	A plant was purchased but it never worked
Guadalajara, Mexico	A plant (160 t/shift) worked during 15 years
Monterrey, Mexico	A plant (160 t/shift) worked during 15 years
Villa Hermosa, Mexico	Inactive.
Oaxaca, Mexico.	A plant (80 t/shift) was in operation. It is not known if it continues working
Toluca, Mexico	Inactive
San Salvador, El Salvador	Closed for more than 25 years
Medellin, Colombia	It never worked
Venezuela	A plant was purchased but it never worked.
Quito, Ecuador.	Pilot plant of 5 t/shift with rotary biodigestor. It is not working

Cuenca, Ecuador	Pilot plant with rotary biodigestor. It is not working
Guayaquil, Ecuador	The installation of a plant that never worked generated a political crisis
Brasilia, Brazil	Two plants working in Brasilia
Brazil.	Small plants have been installed but have not been evaluated in the medium term. São Paulo, Brasília and Rio de Janeiro have large plants. In Rio de Janeiro, two plants with a joint capacity of 1,800 t/d and a total cost of US\$ 40 million were installed and have had difficulties in start-up. According to a study carried out by the Instituto de Pesquisas Tecnológicas de São Paulo, IPT, in 19907 there were 57 composting facilities with incorporated recycling; from that total, 18 were operating, 15 under construction and the 24 remaining were out of order

Source: PAHO. *El manejo de residuos sólidos municipales en América Latina y el Caribe*. 1995. *Serie Ambiental N° 15*

Some demonstration projects of solid waste recovery and bioconversion promoted and sponsored by NGOs and operated by the community, have succeeded. However, they succeeded as projects of academic value and demonstration of technical process, but only in few cases the experience has been maintained or replicated widely because they did not have institutional, administrative, economic and financing self-sustainable mechanisms.

Table 5 Treatment costs Costs of alternative treatment methods

Method	Investment cost in US\$ per installed	Operation cost in US\$ per (with amortization)
Sanitary landfill, USA	S/D	\$30 (varies from 15 to 60)
Sanitary landfill, LAC (**)	5,000 - 15,000	\$6 (varies from 3 to 10)
Composting	20,000 - 40,000	\$25 (varies from 20 to 40)
Incineration, USA (*)	125,000 - 160,000	\$60 (varies from 50 to 90)

(*) The cost per ton is the net cost after selling the energy. The gross cost would be US\$ 90 per ton.

(**) The technical specifications of sanitary landfills in USA are more stringent than LAC countries, which affects the costs.

Source: PAHO. *El manejo de residuos sólidos municipales en América Latina y el Caribe*. 1995. *Serie Ambiental N° 15*

In Table 6 data on treatment in some LAC cities are shown. Except for the case of cities near to agricultural and industrial complexes, it is unlikely to see the private sector interested in investing and operating composting plants unless they are small industrial projects for a reduced local market of gardens and domestic plants. Successful worm breeding projects to produce humus have been reported in Colombia, Cuba, Peru and Brazil, but they are experimental, carried out at a very small scale and with technical and social assistance. It is known that some demo projects of waste anaerobic digestion have

shown technical feasibility, but they have not been implemented because their cost-effectiveness has not been demonstrated.

Table 6 Treatment of MSW in some cities

City	Sanitary landfill *	Incineration	Composting	Recycling in plant	Other treatment	Treatment financing
Sao Paulo	94%	1.1%	4.5% (500 t/d \$0.05/t	0.4%		Subsidized
Rio de Janeiro	81%		900 t/day Pri	4%		Subsidized
Brasilia	73%	1%	13%	3%		Subsidized
Mexico	92%	Inactive	200t/day	7%		Subsidized
Montevideo	99%	1%				Subsidized
Cali	90%		70t/day. \$24/t			Subsidized
Havana	100%				Plants for processing	
Asuncion	100%					
Santiago,Chile	100%				Biogas recovering	

*Some of them are controlled landfill

Source: PAHO. *El manejo de residuos sólidos municipales en América Latina y el Caribe. 1995. Serie Ambiental N° 15*

4.3 SANITARY LANDFILL

Table 6 shows that among 33 large cities, 30% of the refuse goes to sanitary landfills and 35 % to semi-controlled landfills. The remaining facilities do not meet minimum sanitary standards and can be classified as garbage dumps. If these figures are compared with those from one decade ago, good progress is evident. This only occurs, however, in some large cities that due to their size produce statistical diversions which may lead to an exaggerated optimism. Indeed, the situation in most cities is not favorable. Additionally most of the so-called sanitary landfills do not meet enough of the technical specifications to be recognized as such, not even sufficiently to be considered as controlled landfills. In Brazil, in a nation-wide survey, 88% of the cities had open dumps, 9 % had controlled landfills and 3 % had sanitary landfill or other adequate final disposal method. In Chile, the coverage of solid waste disposal in sanitary landfills is 83% at the national level. From a total of 409 cities, 184 have sanitary landfills; thus, Chile is considered a leader in this type of final disposal in LAC. In the Region, waste moisture and composition determines reactions in sanitary landfills different from those described in the technical literature from developed countries. The density of compacted refuse is greater (800 to 1,000 kg/m³), which extends the life of landfills beyond the expected. With 50% of moisture, the field capacity is reached rapidly in the landfill with the compaction; thus, the methanogenic stage of the decomposition occurs and biogas is produced. Biogas is used in gas distribution networks in Santiago and Valparaiso (Chile) and was used in the decade of 1980 as fuel for trucks and light vehicles for supervision in Rio de Janeiro (Brazil). It is worth mentioning that none of the two countries are oil exporters. If the 330,000 daily tons of urban refuse produced in the Region were disposed in sanitary landfills, a 380,000 in' area would be required for disposal daily. This gives an idea of the land demand and the need to design strategies so that operating agencies have priority in municipal planning to obtain urban or suburban areas. In the Region, operation cost for a sanitary landfill varies from 3.00 to 10.00 dollars per ton, depending on the size, quality of operation, topography and hydrogeological conditions of the site. In the United States, the average cost is 30 dollars per ton due to the strict legislation (PAHO,

Serie Ambiental, 1998). It should also be noted that no country of the Region treats leaching, it is infiltrated into the subsoil or discharged in surface waters instead. The city of Santiago recirculates these liquids in landfills because rain is scarce. In several cities, new designs are already considering treatment, such as in Buenos Aires and the Federal District of Mexico. Another aspect that has received attention is the inclusion of the cost of the landfill after its closure in the cleaning service tariff (Buenos Aires and Santiago), taking into account the difference between cost and price.

Table 7 shows data on sanitary landfills from some cities of the Region provided by service operators. However, reports from Argentina, Brazil, Chile, Costa Rica, Peru, Trinidad and Tobago, Venezuela, and sector studies carried out by PAHO in Colombia, Guatemala, Mexico, and Uruguay indicate that coverage and quality of sanitary landfills are lower than those indicated in that Table 7 summarizes this information on quality and coverage of sanitary landfills in 11 countries of the Region.

Scavengers are a problem in almost all cities and make the sanitary landfill operation unsafe. It is necessary to make a difference between landfill scavengers and those from the city. When there are landfill scavengers, it is not possible to develop a real sanitary landfill. To yield to the social demands that allow recycling in landfills and to keep essential rules of operation makes the difference between a second-rate landfill and a real sanitary landfill. One of the major problems is to operate sanitary landfills in small cities with less than 50,000 population, that produces little refuse, because the high cost of a tractor is not justified due to scale economies. It is worth mentioning the manual sanitary landfills program of Colombia, which can be a solution to this type of problem. In Chile, substantial progress has been achieved in cities with less than 20,000 population since from 342 locations, 22% (69 localities) have access to sanitary, manual or mechanized landfills. There are experiences in many countries, but mostly at a pilot project level.

Table 7 Data on sanitary landfills in some cities

City	Landfill quality (method)	Percentage waste filled	T/day	Landfill number	Biogas ventilation	Biogas use	Landfill cost \$
Mexico D.F	Good (area)	50%	5,000	1	Yes	No	4.00 (op.)
Lima, Peru	Regular (area)	30%	1,500	2	Yes	No	4.00 (op)
Rio de Janeiro, Brazil	Good (area)	81 %	5,500	3	Yes	Yes	4.00
São Paulo, Brazil	Good (area)	94%	11,800	3	Yes	No	12.00
Santiago, Chile	Good (area)	100%	4,600	2	Yes	Yes	6.00
Havana, Cuba	Regular (area)	80%	1,500	2	No	No	
Caracas, Venezuela	Regular (area)	100% -	3,400	2	Yes	No	
San Jose, Costa Rica	Regular (area)	100%	500	2	No	No	2.90
Bogotá, Colombia	Good (area)	100%	4,200	1	Yes	No	2.70
Buenos Aires, Argentina	Good	100%	9,600	5	Yes	No	10.00
La Paz, Bolivia -	Good	100%	350	1	Yes	No	
Medellín, Colombia	Good -	100%	750	1	Yes	No	
Guayaquil, Ecuador	Good	100%	1,400	1	Yes	No	2.20
Rosario, Argentina -	Regular	100%	700	1	No		
Brasília, Brazil	Regular	75%	1,100	1	No		
Curitiba, Brazil	Good	100%	1,300	1			
Monterrey, Mexico	Regular	100%	2,400	1	No	No	
Trinidad and Tobago	Regular	100%	1,200	3	Yes	No	5.40

Source: PAHO. *El manejo de residuos sólidos municipales en América Latina y el Caribe*. 1995. Serie Ambiental N° 15.

PAHO. *Sistema de Monitoreo de Residuos Urbanos, SIMRU*. 1996.

Lectures presented at the XXV Congress of AIDIS in Mexico, 1996.

Table 8 Information on sanitary landfills in some countries of Latin America and the Caribbean

Country	Information on sanitary landfills
Argentina.	There are five sanitary landfills located in the metropolitan area of Buenos Aires and one in Cordoba
Brazil	It is estimated that no more than 3 % of 40 thousand tons of refuse collected daily have adequate final disposal.
Chile.	83 % of the waste collected in 184 cities is disposed of in sanitary landfills
Colombia	Except in Medellin and Bogota, there are no sanitary landfills in the country.
Costa Rica.	There are one sanitary landfill and one controlled landfill
Ecuador	There is one sanitary landfill in Guayaquil and controlled landfills in Quito
Guatemala	There are one sanitary controlled landfills in the country.
Mexico	It is estimated that there are only 10 to 15 sanitary landfills in the country, including two in the Federal District.
Peru	There are no sanitary landfills in the country
Trinidad and Tobago	In Trinidad there are three controlled landfills and in Tobago there is one controlled landfill.
Uruguay	There are no sanitary landfills
Venezuela	In 11 zones under study, covering 38 municipalities served and the metropolitan area of Caracas, there are no sanitary landfills.

Source: PAHO; IDB. *Informe de expertos locales para el presente diagnóstico*. 1996. PAHO. *Estudios sectoriales de residuos sólidos en cuatro países*. 1995-1996.

In the last 10 years, the use of sanitary landfills has increased in the Region and all the capitals and large cities of LAC and Trinidad and Tobago in the Caribbean have sanitary landfills or the so-called controlled landfills. Usually, in the latter, collector trucks are controlled in the gate but the load is not weighed; scavenger settlements are not allowed within the landfill area, but a classified waste segregation is allowed; waste is compacted and covered daily; non-waterproof method or material is used; in some, biogas is ventilated; leaching is not collected or treated; and quality ranges from those landfills with characteristics close to a sanitary landfill up to open dumps (Table 8).

Cities such as Belo Horizonte, Buenos Aires, Guayaquil, Medellin, Mexico City, Querétaro, Santiago and São Paulo have real sanitary landfills, some of them even use synthetic membranes as impervious

material. Several landfills are operated by private utilities, such as in Argentina, Brazil, Chile, Colombia, Ecuador, Mexico, Panama, and Peru. Usually, land is provided by the municipality and concessionnaires operate them in accordance with technical specifications given by the local authority; in turn, they charge the municipalities through an invoice, according to weight or volume of wastes. Sea dumping of MSW is prohibited by international agreements. In several countries of the Caribbean, however, it is an environmental and health problem demanding immediate solution since it affects them by reducing tourism. Countries such as Brazil, Peru, Chile, St. Vincent, Guyana, and Ecuador (Global Waste Survey IMO, 1995) declared that they were disposing of their wastes in the sea, despite these international agreements. In some cases, sea dumping of MSW was part of projects to recover seashore lands. Once completed, sanitary landfills may become green and sports areas, as it is observed in Buenos Aires, Mexico City, São Paulo, Porto Alegre, and other sites.

4.4 ENERGY FROM MUNICIPAL SOLID WASTE

At present, there is much interest in energy production from MSW that generally comprises a mixture of organic matter (food wastes), plastics, paper, glass, metal and other inert parts. It can also include some commercial and industrial waste that is similar in nature to household waste. MSW is primarily considered a liability. It needs to be collected and processed, which comes at a certain cost. If managed improperly, it can cause severe human health problems and harm the environment. However, MSW also represents an opportunity, for example for recycling and re-use of materials in the waste stream, and for the production of energy. Energy from MSW is often seen as a great opportunity for developing countries to produce energy from a cheap and readily available resource. However, it also raises a few questions:

- Can MSW be classified as biomass?
- Is energy produced from MSW renewable?
- Can MSW offer a significant contribution to the energy supply of developing countries?

Some key facts on MSW

- World MSW production is estimated at 2 billion tons per year
- MSW production per capita is approximately 0.5 kg/day in developing countries, against 1.6 kg/day in industrialized countries (WB, 2008)
- The energy potential of MSW depends on its composition and the processing technique. MSW incineration in industrialized countries results in both 400-600 kWh of electricity per tonne of waste and at least as much heat. Electricity produced from landfill gas (LFG) extracted from a well-designed and operated landfill can be up to about 200 kWh per ton—albeit over a long period of time (15-25 years). (DEFRA, 2004)
- Compared to industrialized countries, MSW in developing countries contains more food and inert materials, and less paper and recyclables. Its moisture content is higher and its calorific value is lower. (Cointreu, 2005)

Energy generation from MSW

In general, the processing of MSW is primarily intended to dispose of the waste and/or reduce its volume. Common techniques are landfilling and incineration. Energy recuperation can be an important part of the process, particularly in industrialized countries. There are several ways in which the energy recuperation can take place (see figure 1).

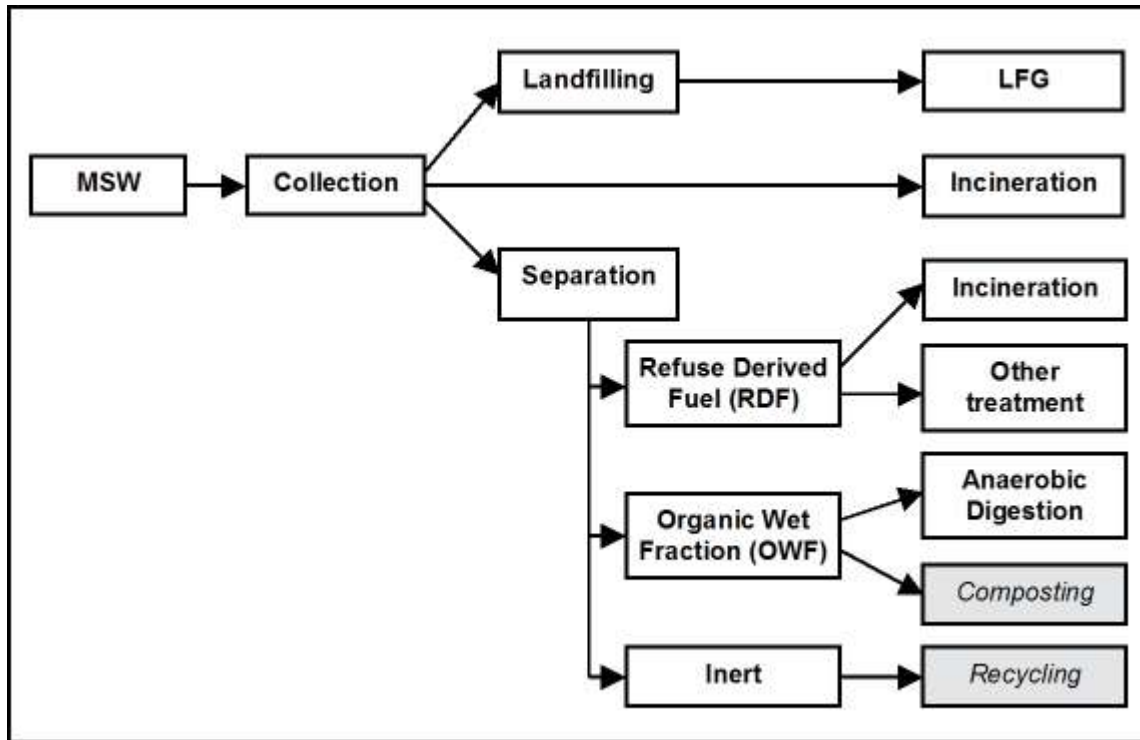


Figure 1. Pathway for Energy recovery

Landfilling with landfill gas (LFG) recovery

When MSW is landfilled, the organic components start decomposing in an anaerobic digestion process. This process results in the formation of landfill gas, which consists primarily of methane and CO₂. The landfill gas can be extracted from the landfill using a system of pipes, and can then be used for energy generation in gas engines, turbines or boilers. The rate of decomposition in an ordinary landfill is low: it takes decades before the organic material is fully digested. Gas production will initially increase, but after having peaked (after about 10 years) it slowly decreases. After 20-30 years, gas production may drop to less than half of the peak amount, making it less economical to use for energy generation. The main advantages of landfilling are low investment and operational costs. Initial investments in a landfill of 500 tons/day are in the order of US\$ 5-10 million, and costs for operation and maintenance of a landfill are approximately US\$ 10-20 per ton of MSW. These costs are limited in comparison to the cost of collection and transfer of MSW; in developing countries these costs amount to around US\$ 30-50 per ton (Cointreu, 2005). On the other hand, improperly designed or operated landfills may cause severe risks to human health and to the environment, for example through ground

water contamination or greenhouse gas emissions from landfills. This is the case in most developing countries, where MSW is often dumped rather than landfilled.

4.5 INCINERATION: WTE

Raw MSW consists for a large part of food residues, paper and plastics. Its energy content depends on the actual composition, but in general it will be between 8-12 GJ/ton (comparable to fresh wood). In most industrialized countries it is incinerated in Waste-to-Energy installations in which the energy is turned into electricity and also heat, which can be used for district heating, process heat for industry, or cooling systems. The total energy recuperation rate may be relatively high. Another advantage of incineration as a processing means is that it results in a large waste volume reduction (80-95%) (Rand & Marx, 1999), which greatly reduces the space required for disposal. Also, if proper emission reduction measures are taken, incineration is a clean means of waste processing. It is, however, an expensive option, both in terms of investment costs and operational costs. Investment costs of a modern 1,200 ton per day incineration plant in Europe are in the order of US\$ 300-400 million, while the processing costs are about US\$ 100-150/ton—half of which are capital costs (Gijlwijk & Ansmens, 2004). The main reason is the high cost of emission control, which is required for environmental considerations. Furthermore, WTE is only applicable when a number of overall criteria are fulfilled (Rand & Marx, 1999):

- The existence of a mature and well-functioning waste collection and management system for a number of years.
- A minimum and stable supply of combustible waste (at least 50,000 tons/year).
- A minimum average lower calorific value (at least 7 MJ/kg, never below 6 MJ/kg).
- A community is willing to absorb the increased treatment cost.
- Skilled staff that can be recruited and maintained.
- Solid waste disposal at controlled and well-operated landfills.
- A stable planning environment of the community (planning horizon at least 15 years).

All in all, the applicability of incineration in developing countries is limited. Experiences with waste incinerators that were built in developing countries have not shown great success. For example, most World Bank supported incineration projects were closed as the local wastes did not have sufficient calorific value to sustain combustion without adding additional fuels (Cointreu, 2005).

4.6 SEPARATION

MSW is increasingly separated into different fractions using a series of washing and sieving steps. Part of the waste (e.g. metals) can then be recycled, while other fractions can be used for energy generation. The latter consist particularly of Refuse Derived Fuel (RDF), a mixture of relatively high calorific components (paper, wood, plastics) which can be incinerated in Waste-to-Energy installations or upgraded to secondary fuel, and the Organic Wet Fraction (OWF) from the MSW, which can be used for biogas production (Oorthuys, 1999). Investments and processing costs are moderate. The investment costs for a modern 1,200 ton per day separation and anaerobic digestion installation are in the order of US\$ 100 million, and the processing costs are about US\$ 100/ton. (Gijlwijk & Ansmens, 2004)

4.7 OTHER PROCESSING TECHNIQUES

Other processing techniques that are in various stages of development are pyrolysis and (plasma) gasification. For MSW applications these processes have not yet been commercially proven.

5. MUNICIPAL SOLID WASTE

5.1 MSW ISSUES IN DEVELOPING COUNTRIES

In most low- and middle-income countries, the collection, transport and processing of MSW poses large problems. Often quoted problems are the following: The costs of collection, transport and processing weigh heavily on municipal budgets. It is quite common that 20-40 per cent of municipal revenues are spent on MSW management, while the majority of inhabitants remain unserved (Zerbock, 2003). The capacity of the MSW collection and transporting system is often inadequate. Rapid urbanization overstretches MSW collection and processing capacity. In some cases, up to 80 per cent of the equipment is not operational.

Weak government structures are frequently named as a major problem. Responsibilities are often shared by elected and non-elected individuals who may not be held accountable for the proper functioning of the system. Because of the high costs, the first and foremost concern in many countries is to get the waste out of the urban areas. Further processing is of lesser importance, and in most cases the collected waste is dumped outside of the city. Often, part of the waste is burned in uncontrolled fires. Scavenging (waste-picking) is common practice, and provides a source of income for considerable groups of people.

5.2 THE FUTURE ROLE OF MSW AS BIOMASS FUEL

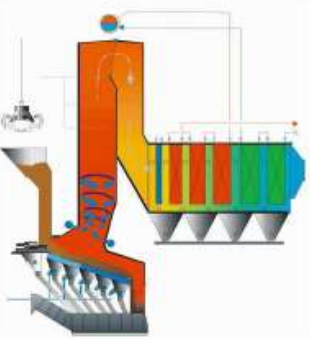
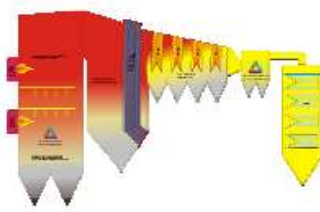
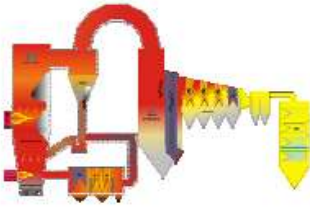
To what extent can MSW be considered a valuable source of renewable energy? First of all, energy from MSW can be seen as sustainable. MSW does in no way compete with food, as it does not claim land that could be used for food production. From this point of view it is an energy source that could be used to its fullest potential. Furthermore, societies will always be producing municipal waste so its availability is reliable. However, the extent to which MSW can contribute to the energy mix is limited. The 2 billion tons of waste produced annually around the world could theoretically produce up to about 5 per cent of the world's total electricity. Electricity generated from MSW constitutes less than 1 per cent of the total electricity generated in the EU today (Wielenga, 2008) although its contribution is expected to double by 2020. On the other hand, in developing countries there is very little energy recuperation from MSW so there is still large growth possible. For LAC, energy from MSW will concern mainly landfill gas capturing and usage, made possible by CDM funding. Recent years have shown a considerable growth in the number of landfill gas projects under CDM, although landfill gas is still mostly flared rather than used for electricity production. Besides, not all projects are successful, and gas yields are often much lower than anticipated. It is not expected that waste incineration will play a significant role in LAC in the foreseeable future (Cointreu, 2005). MSW from low and middle-income societies is unfit for incineration due to its composition (little plastics and paper, high moisture content), unless the waste is

separated or additional fuels are used during combustion. The higher investment and operational costs in comparison to landfilling form an additional barrier.

6. WTE TECHNOLOGIES

6.1 PROVEN TECHNOLOGIES

Combustion is the dominant commercially viable WTE technology today. Gasification is distant second with only a few facilities in commercial operation primarily in Japan. Several alternative technologies are on the experimental and pilot stage. The 3 main combustion technologies used are grate systems, bubbling fluidized bed (BFB) and circulating fluidized bed (CFB) systems. (Rundqwist, 2009)

GRATE	BUBBLING FLUIDIZED BED	CIRCULATING FLUIDIZED BED
		
<p>6-16 MJ/kg (LHV)</p> <ul style="list-style-type: none"> • MSW Untreated • Industrial waste • Wood waste • Hospital waste • (co-firing) Sludge (co-firing) 	<p>3-20 MJ/kg (LHV)</p> <ul style="list-style-type: none"> • MSW Pretreated • Rejects • Sludge • Biomass • Wood waste 	<p>6-42 MJ/kg (LHV)</p> <ul style="list-style-type: none"> • MSW Pretreated • Rejects • Sludge (co-firing) • Biomass • Wood waste • Coal • Pet coke

Grate

Grate combustion is the most thoroughly tested technology for thermal treatment of waste. There are over 1000 plants worldwide and the systems have been continuously optimized and upgraded to changing standards. Today grate combustion is the most advanced technology in terms of environmental safety, reliability, flexibility and cost effectiveness. At the heart of the system is the grate. Waste metered from a feed hopper is conveyed by the grate through the combustion chamber where it is burned, normally without additional fuels. Primary combustion air is injected below the grate directly into the fuel; secondary air (mixed with recirculated flue gas in some designs) enters the secondary combustible chamber from above the grate. The burned-out slag is discharged at the end of the grate. The whole process, from waste metering to grate speed and air supply, is under continuous control to ensure optimum combustion. The grate stands out for its robust construction and its resistance to strongly heterogeneous waste. The steam generator located downstream of the combustion grate extracts energy from the hot combustion gases in the form of power generation. Flue gas treatment begins right in the combustion chamber, which is engineered to prevent most pollutants from being generated in the first place. Downstream components conform to fuel properties, residue disposal practices and emission limits. Customized concepts make it possible to guarantee emission levels far beyond those of the world's toughest pollution standards.

Fluidized Bed

Bubbling and circulating fluidized beds are also suitable for thermal treatment of pretreated waste. It features high thermal capacity and can handle a wide range of fuels and heat values. A single system can treat waste with low and very high heat values. The fluidized bed can process other fuels such as biomass, sludge, coal and pet coke separately or together with waste. The heart of the fluidized bed is the bed itself. The turbulence in the fluidized bed, combined with the scouring effect and the thermal inertia of the bed material, provide for complete, controlled, and uniform combustion. The scrubbing action of the bed material on the fuel particles enhances the combustion process by stripping away the char layers that normally form around the fuel particle. This allows oxygen to reach the combustion material much more rapidly and increases the rate and efficiency of the combustion process.

These factors are the key to maximizing thermal efficiency, minimizing char, and controlling emissions. The high combustion efficiency in a fluidized bed makes it particularly well suited for problem fuels with high moisture contents and low heating values. In typical fluidized bed systems, the carbon emissions are inherently lower than those from conventional technologies for the following reasons: The low combustion temperature and the low excess air within the bed reduce the formation of nitrous oxides or NO_x. A further reduction can be achieved by installing a Selective Non-catalytic Reduction (SNCR) system which will meter urea or ammonia solution into the flue gas flow. The high combustion efficiency results in low carbon monoxide (CO) content in flue gases. For fossil fuels containing sulfur, emissions such as SO_x may be reduced in situ within the boiler by adding lime to the bed, which normally eliminates the need for downstream DeSO_x flue gas cleaning systems. Most other emissions, which may result from specific fuels, can easily be handled by injecting reactive agents such as sodium bicarbonate and activated carbon into the flue gas and removing them in a baghouse filter or ESP. Like the grate system, customized concepts make it possible to guarantee emission levels far beyond those of the world's toughest pollution standards.

6.2 CURRENT STATE OF WTE TECHNOLOGY

The dominant WTE technology is mass burning, because of its simplicity and relatively low capital cost. The most common grate technology, developed by Martin GmbH (Munich, Germany), has an annual installed capacity of about 59 million metric tonnes. The Martin grate at the Brescia (Italy) plant is one of the newest WTE facilities in Europe. Figure 2 shows a schematic diagram of its mass-burn combustion chamber. The Von Roll (Zurich, Switzerland) mass-burning process follows with 32 million tonnes worldwide. All other mass-burning and refuse-derived-fuel (RDF) processes together have a total estimated capacity of more than 40 million tonnes.

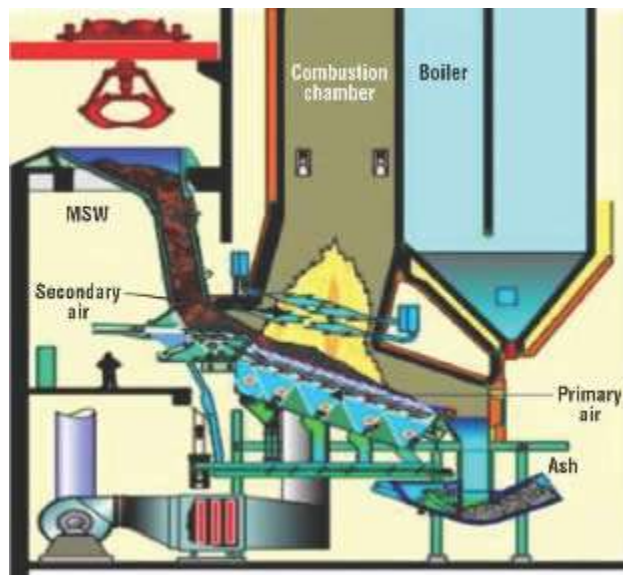


FIGURE 2. Schematic diagram of the Brescia mass-burn combustion chamber.
Source: (Bonomo, 2003)

The SEMASS facility in Rochester, Massachusetts, USA, developed by Energy Answers Corp. and now operated by American Ref-Fuel, has a capacity of 0.9 million tonnes/year and is one of the most successful RDF-type processes. The MSW is first pre-shredded, ferrous metals are separated magnetically, and combustion is carried out partly by suspension firing and partly on the horizontal moving grate (Figure 3)

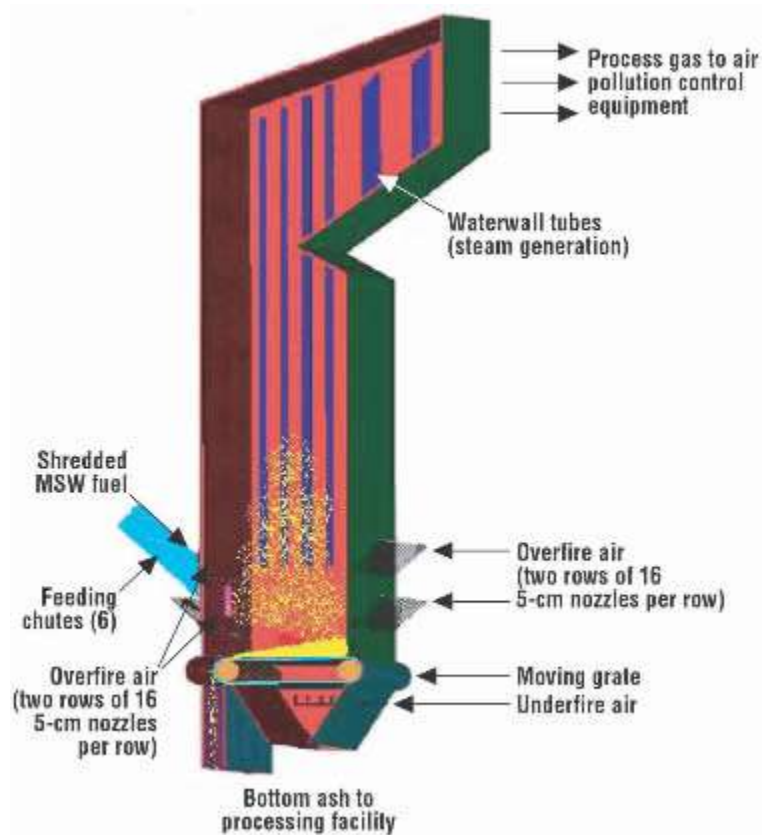


FIGURE 3. Schematic diagram of the SEMASS process at Rochester, Massachusetts, USA

Table 9 shows the enormous expansion in global WTE capacity, in terms of new Martin and Von Roll plants, that has taken place since 1995. A total of 154 WTE facilities have been constructed or are currently under construction, totalling to a capacity of 16.5 million tonnes.

Table 9. Expansion on WTE capacity.

Major trends in new WTE construction, 1996-2003	Martin plants ^a		Von Roll plants ^b
	Reverse grate	Horizontal grate	
Number of new plants, 1996-2001	41	21	55
Installed total new capacity, 1996-2001, tonnes/year	7,800,000	3,100,000	3,500,000
Average plant capacity, 1996-2001, tonnes/year	182,000	148,000	64,000
Number of new plants, since 2001 (plus those under construction)	27	6	14
Total new capacity since 2001, tonnes/year	4,100,000	740,000	1,150,000
Average plant capacity since 2001, tonnes/year	151,000	134,000	82,000
Largest plant built in 1996-2003, tonnes/year	1,400,000	480,000	250,000
^a Martin capacities were obtained by multiplying reported daily capacities by 330. ⁵			
^b Von Roll capacities were calculated by multiplying reported hourly capacities by 24 x 330. ⁶			

Source: (Gmbh), (Botero, 2010) (Von Roll Inova Corp.)

6.3 WTE EMISSIONS

In the late 1980s, WTE plants were listed by the US Environmental Protection Agency (EPA) as major sources of mercury and dioxin/furan emissions. However, in response to the Maximum Available Technology (MACT) regulations promulgated in 1995 by the US EPA, the US WTE industry spent more than one billion dollars in retrofitting pollution control systems and becoming one of the lowest emitters of high temperature processes. The US EPA recently affirmed that WTE plants in the US 'produce 2800 MW of electricity with less environmental impact than almost any other source of electricity' (Themelis, 2004)

6.4 ENVIRONMENTAL BENEFITS OF WTE

Despite the great reduction in emissions attained by WTE facilities in the last 15 years, some environmental groups in the US continue to oppose new WTE facilities on principle, unaware that the only alternative for MSW disposal - landfills - have much larger environmental impacts. For every tonne of waste landfilled, greenhouse gas emissions in the form of carbon dioxide increase by at least 1.3 tonnes. During the life of a modern landfill and for a mandated period after closure, aqueous effluents

are collected and treated chemically; however, chemical reactions and volume decrease of the landfilled MSW can continue for decades and centuries. Thus, there is potential for future contamination of adjacent waters.

6.5 THE NEXT GENERATION OF WTE PROCESSES

The existing WTE combustion chambers have been developed largely empirically. Their size, percentage of excess air used, and the volume of process gas are much larger than for coal-fired power plants of the same combustion capacity. Therefore, the capital and maintenance costs of a WTE facility are nearly three times as high as that for a coal-fired power plant generating the same amount of electricity. One of the objectives of the Waste-to-Energy Research and Technology Council is to apply engineering science in understanding the phenomena occurring in the best of the existing WTE processes and then to implement this knowledge during the design of the next generation of WTE facilities. Two obvious means for increasing the turbulence and transport rates in the WTE chamber are oxygen enrichment, as practised in the metallurgical industry, and flue gas recirculation. The latter has already been implemented very successfully in the Brescia WTE facility. Also, Martin GmbH has already piloted oxygen enrichment on a large scale and is in the process of building two 'next generation' plants, in Arnoldstein, Austria, and in Sendai, Japan, in collaboration with Mitsubishi Heavy Industries. Figure 4 is a schematic diagram of the Martin Syncom-Plus process that will be used in these plants. In addition to oxygen enrichment of the air injected through the grate, Syncom-Plus makes use of an infrared camera for monitoring the temperature of the bed on the grate and a sophisticated control system to ensure complete combustion and produce a bottom ash that is nearly fused and ready to be used beneficially.

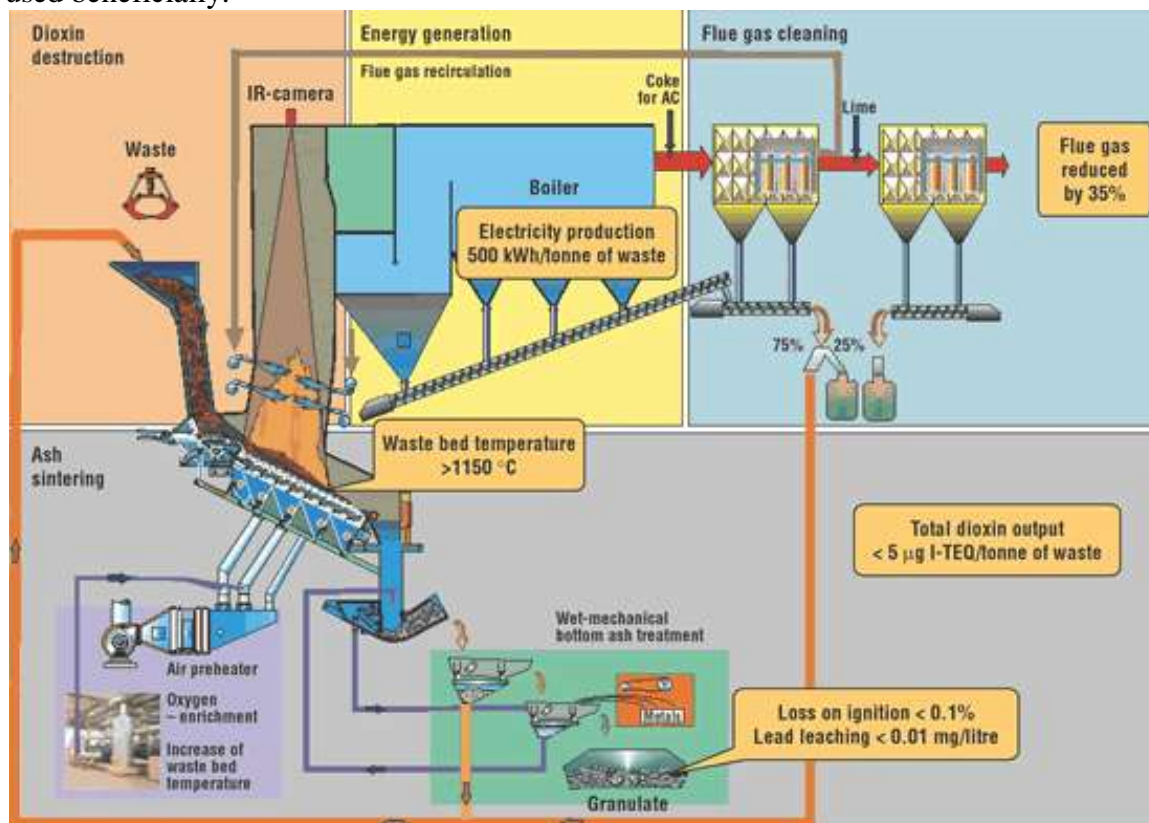


FIGURE 4. The Syncom-Plus process of Martin GmbH

Source: (Gmbh)

6.6 THE WTE RESEARCH AND TECHNOLOGY COUNCIL

During the course of several graduate studies of various facets of integrated waste management, the Earth Engineering Center (EEC) of Columbia University came to the realization that, despite the importance of WTE technology to the US, there were no industrial or government research centres dedicated to advancing the WTE technology. The only organization addressing the concerns of the US WTE facilities and of the major WTE companies (American Ref- Fuel, Covanta Energy, Montenay-Onyx, and Wheelabrator) is the Integrated Wastes Services Association (IWSA) formed in 1991. Its role does not include R&D, however.

Therefore, in the spring of 2002, EEC and IWSA, with the help of Columbia's Earth Institute, founded the Waste-to- Energy Research and Technology Council (WTERT). One of the objectives is to link academic research groups working on various aspects of WTE technology, as well as engineers in the WTE industry and government agencies concerned with waste-to-energy and integrated waste management. The mission of the Council is to advance both the economic and environmental performance of waste-to-energy technologies, and this includes both conservation of resources and environmental quality.

At the present time, WTERT is sponsored by its founders, the US EPA, the Solid Wastes Processing Division of ASME International, the Municipal Waste Management Association of the US Conference of Mayors, and other organizations. One of the services provided by WTERT is the interactive database 'SOFOS' that provides information on technical papers and reports related to the integrated management of solid wastes.

The following academic groups are currently participating in the WTERT University Consortium:

- Earth Engineering Center, Department of Earth and Environmental Engineering, and Department of Civil Engineering, Columbia University, USA
- Marine Sciences Research Center, State University of New York at Stony Brook, USA
- Department of Civil and Environmental Engineering, Temple University, USA
- Department of Applied Earth Sciences, Delft University of Technology, the Netherlands
- Sheffield University Waste Incineration Center (SUWIC), UK.

WTERT welcomes other universities interested in the goals of the Council to join this consortium.

6.7 DRIVING FORCES TOWARD MATERIAL RECYCLING AND WTE IN EUROPE

The European Union has been implementing few changes on legislation and regulations to promote progress on two environmental challenges: reducing greenhouse gas emissions and disposing of their garbage more sustainably. These important objectives can be met by lifting the state's ban on building waste-to-energy facilities. By doing that, Europe has reduced use of landfills by 65 percent and replaced those with waste-to-energy facilities and greater recycling. China plans to kick the coal habit in part through waste-to-energy. Their goal is 30 percent of their waste stream dedicated to energy production.

Germany is already at 30 percent; Denmark is currently even higher - 55 percent of its waste stream goes to creating clean energy. (EU, 1999)

European Policies on Landfill Ban

- The EU Landfill Directive
- The amount of biodegradable waste has to decrease with 35% until 2016, compared with the situation in 1994. (UK and Ireland extension until 2020, for the 12 new Eumembers until 2025)
- Ban already in a number of countries on landfilling of biodegradable waste.
- The Ban often completed with a Landfill Tax.

European Examples on the effect of Landfill Ban and of Landfill Taxes

Germany

Landfill Ban decided upon in 2000, in force in 2005.

A very strong effect, with a strong increase of Waste-to-Energy, and other recycling methods. However, initially, a lot of waste flowing out of Germany due to a significant lack of Waste-to-Energy capacity

Austria

As Germany, but Ban in force already in 2002.

Landfill Tax since 1997/98.

Increased Waste-to-Energy but also of other recycling methods.

Denmark

Landfill Ban in force already in the 1990-ies, as well as a Landfill Tax.

Increased Waste-to-Energy and material recycling

At the beginning a lot of belief and investment in biological treatment, but now more or less closed down for environmental (odours) and economical reasons

United Kingdom

No Landfill Ban (extension until 2020)

About 60% of the household waste is still landfilled.

Slow advancement of material recycling as well as of Waste-to-Energy.

Producers Responsibility

- EU Directive on Recycling of Packaging Waste in force in 1995 – with recycling targets for different packagings.
- Implemented as full or shared producers responsibility in different countries (by law in Austria, Germany and Sweden)
- Resulting in increased material recycling (of packaging).
- EU Directive on full Producers Responsibility on WEEE, Batteries and End-of-Life-Vehicles.

7. WTE: A MARKETING VIEW IN LATIN AMERICA.

Many countries in Latin America, for the first time, are beginning to explore the use of waste-to-energy plants as part of their integrated solid waste management plans. Geopolitical and global economic pressures have caused governments to re-evaluate how infrastructure services can be more effectively and economically procured, without degradation of quality of service and the environment. Some countries, for the first time, are passing laws enabling privatization of many historically publicly owned and operated, infrastructure services, such as electricity generation, drinking water and waste-to-energy plant ownership and operation. This is being done in an effort to gain state-of-the-art technology while lowering the cost of infrastructure services. The political events of the past ten years, and the continued emergence of a global economy, has shown the need to procure infrastructure services in a less costly way.

In this context, Latin America is actively seeking out, and wanting to apply the advancements made by U.S./Europe waste-to-energy companies in the last two decades. Waste-to-energy companies may be interested in new business opportunities for their systems in overseas markets. However, there are many obstacles to overcome in marketing technology and waste disposal services in developing countries.

Where are those markets of opportunity? There are three criteria which can be used to screen for potential waste-to-energy markets: 1. Living standards; 2. Limitation on land use; and, 3. Rule of law. What are the cultural, geographic and competitive obstacles in marketing overseas? Can obstacles such as language, development costs, time zone differences, institutional experience with privatization, local and foreign competitive advantages be managed or mitigated? An understanding of how a global economy impacts the marketing of waste-to-energy services is essential to formulate an overseas marketing plan.

7.1 MARKET SCREENING

The demand for waste-to-energy plants will grow as countries transition to privatization of infrastructure services. The shift to private ownership of waste-to-energy plants with the commensurate risks and rewards will make WTE know-how valuable in the competitive market place. However, the first challenge for WTE companies is to identify markets that are potentially viable for waste-to-energy services. While there is intense interest overseas in advanced technologies and new business opportunities, there are few areas of the world that can realistically implement waste-to-energy technology. Waste-to-energy technology is expensive, and there are numerous institutional and business factors that have to be in place before hundreds of millions of dollars can be invested in a business venture half way across the globe. With this as a premise, there are a few basic criteria that can be used to screen markets opportunities. Potential WTE markets should meet the following criteria:

1. Country/market must have a high standard of living. In general, the country must have successfully addressed other high priority infrastructure services such as energy, water, food, housing, health care, education, etc. If these basic services are not adequate it is not likely there is money or the political will to pay for expensive waste-to-energy disposal services at the expense of food, water, energy and similar basic needs.

2. A simple review of the current budget for waste disposal usually tells the story. For example, if the total collection and disposal costs are \$10 to \$15 per ton (which is not unusual in many developing countries) there is little money in their budget for significantly more expensive WTE disposal alternatives.

3. The country/market has little land for land disposal. Land constraints also occur along heavy populated coastlines -- ocean on one side, people on the other, and no room for landfills. This was one of the criteria exhibited by cities along the eastern seaboard of the U.S., most of which now have waste-to-energy plants.

4. The country/market must be founded in the "rules of law". Due to the long-term nature of the capital investment, the risks of ownership and operation, a country with a reputation of having a fair and unbiased court system is essential. This also applies to the enforcement of internationally recognized standards of contract law, as well as the fairness of the tendering procedures used. Without this, the risks of investment are unacceptable.

Only a few markets in the world meet these criteria. It is certainly possible that WTE plants can and will be built in countries that do not meet these criteria. Government policy decisions can override market constraints. However, enforcement of rules and regulations causing developing countries to use the waste-to-energy plant are critical to the success of these projects.

It is no surprise that markets that meet all these criteria spend the largest sums of money on environmental technologies. The table below shows the amount of money spent in various global environmental markets. The U.S. is the leading market followed by Western Europe, Japan, and the rest of Asia, rounding out the top four. Africa has the least to spend on environmental technologies. Domestic budgets are focused on other, often higher priority, infrastructure needs.

Table 10. THE GLOBAL ENVIRONMENT MARKET

Revenue \$ Billions

Region	2000	2002
USA	195.7	201.8
Western Europe	148.7	155
Japan	90.1	91
Rest of Asia	21.9	27.5
Latin America	11.0	13.7
Canada	13.3	14.2
Australia/NZ	8.2	9.1
Central & Eastern Europe	8.6	12.2
Middle East	6.1	7.5
Africa	3.1	4.2
Total	506.7	536.2

Source: Environmental Business International, Inc., San Diego, CA

Asia deserves some further evaluation. It is a complex mix of cultures and economies. Japan has extensively employed incineration and WTE technologies as a major part of its solid waste management system. A year ago, Japan passed enabling legislation, which permits private ownership and operation of waste-to-energy plants. Clearly, Japan can be categorized as being in the first tier of environmental

spending. The second tier of countries in Asia, are Singapore and Hong Kong, South Korea, and Taiwan. The third tier of countries in Asia is China, India, and Southeast Asia (e.g., Thailand, Malaysia, and Indonesia).

7.2 OVERSEAS MARKET OBSTACLES

According to US companies, there are significant challenges in marketing any product or services overseas. There is the initial spadework required to develop waste-to-energy opportunities sufficiently before it warrants a yes or no decision from senior management. If senior management elects to proceed, the price tag for market entry is hundreds of millions of dollars. The obstacles are many. However, they can be categorized into two groups. First, there are the cultural and geographic challenges, such as language, local customs, and travel time. These are the obstacles we most often believe makes overseas work challenging. The second group of business obstacles is more amorphous. This group encompasses the competitive business challenges associated with overseas work and working in a global economy. This group is often not recognized or under-appreciated as significant impediments to doing business overseas.

7.3 COMPETITIVE BUSINESS OBSTACLES:

Developing countries show diverse obstacles. However, recognizing their impact on marketing WTE services is important in crafting a business strategy for Latin America.

The country must have experience with privatization: Ownership and operation of infrastructure services is usually the purview of a government agency. It is common that governments own, operate, or otherwise subsidize competitive businesses. Privatization of infrastructure services is considered a critical point by U.S. companies. It is then understandable that when countries say they are privatizing their WTE plants, they may have a completely different view of what it means to privatize. With so little experience with private companies taking the ownership and operation risks associated with large public works projects, governments don't have a full appreciation of what fair and reasonable commercial terms are for the service. Because the ownership and operation of infrastructure services has been historically managed by a government agency, if a problem occurred with the operation of service, or a new law was passed affecting the service, matters were worked internally. Service contract issues were not a concern. There were no service contracts. If there was a cost impact due to a change in law, for example, the government paid for it with tax dollars, or the cost impact of the change in law was passed on to users of the service. The commercial terms of the service are, by far, the most difficult issue to address when working in developing countries. Few governments fully appreciate the commercial risks of a DBOO or DBO (design, build, and operate) WTE project. For most governments, privatization is a new concept and they do not understand that the commercial terms of the service contract is a critical element of attracting private investment. WTE projects are, by their nature, complex, often requiring multiple, interrelated agreements. Making matters worse, government procurement agencies are often powerless to change evaluation procedures or accept any exceptions, or recommended changes to the documents issued in the tender. The concept of a negotiated procurement process is unheard of in most markets overseas.

8. BIOMASS

8.1 BIOMASS POTENTIAL

Since developing countries are located predominantly in the warmer climates and lower latitudes, they have a considerable comparative advantage. In terms of today's utilization of biomass resources, this comparative advantage is best illustrated by the development of sugarcane resources in Brazil, mainly for ethanol but also for some industrial products such as bio-plastics.

Latin America, along with sub-Saharan Africa, has been estimated as having the highest biomass potential—after accounting for food production and resource constraints—among any of the major world region (Smeets & Faaji.A, 2004). The high potential results from large areas of suitable cropland, the low productivity of existing agricultural production systems, and the low population density. Such estimates of the long-term bio-energy potential for the various regions can serve as guidelines for development strategies that can harness the biomass resource base in a sustainable manner.

Overall, the global potentials range from 30% to over 200% of current total energy consumption. Other sources of biomass that are not included in the potentials above include animal wastes, organic wastes such as MSW, bio-energy from natural growth forests, and water-based biomass such as micro-algae. It is important to note that these are technoeconomic potentials, and there will inevitably be social and cultural issues that would restrict use of some lands for biomass production. Many other characteristics would have to be considered in assessing the potentials. However, the considerable potential does provide some indication as to the vast scale of land resources and the low levels of current utilization (Matsika, March, 2006)

As the role of biomass for energy and industry has become more economically competitive, there is increasing concern as to the impact on food security, especially for countries that are net food importers or those that experience droughts and other disruptions in the food supply. However, there is not necessarily a negative correlation between food and fuel, and in fact there are many positive economic linkages that can arise. There exist potential synergies between food and non-food uses, especially as new agro-industrial biotechnology methods are deployed. Where there are potential conflicts, it is crucial that bio-based industrial development is accompanied by investment in greater agricultural productivity and/or due consideration for distributional issues that arise when the agricultural sector and industrial sector compete for the same raw materials.

8.2 NATURE OF BIOMASS FEEDSTOCK

Crops can be roughly categorised according to the composition of their (main) economic product as sugar, starch (grains, tubers), oilseed, protein, or fibre crop and crops for speciality products (pharma and cosmetics, dyes, fragrance and flowers). For this purpose the crops have been selected and bred. Beside the main harvested product, all crop processing systems yield more or less secondary products and residues which may find an application depending on demand and possibilities for economical conversion. Biomass residues can be categorised into three main groups: primary biomass residues, available at the farm; secondary biomass residues, released in the agro-food industry; and tertiary biomass, which is remaining after use of products. The characteristics that impact availability and suitability as feedstock include whether the items are of a perishable nature, how much moisture content they have, the density, and the seasonality of supply. Forestry residues are produced in logging

industries in large quantities at the site of harvest (bark, branches, leaves) and in saw and ply mills (saw dust, cut off). Only 25% of the biomass is converted into sawn wood. Other under-utilised biomass resources from primary agricultural production, agro-industries, and municipal waste can be available in high quantities. More uniformly available biomass residues such as straws or seed hulls can be harvested and collected at the farm or at (central) processing sites. Others are only available in dispersed / diluted forms and need collection systems to be installed for concentration and preparation of the biomass. Among the key issues is increasing the use of agricultural residues, which is in some respects an old topic that is now finding new applications in the developing world (ESMAP, 2005). Previously agricultural residues were promoted mainly for energy use, often at low efficiency; however, it is now more widely recognised that there are in fact many uses that may provide higher value-added or could serve as complementary products via co-production schemes alongside energy applications. Such “cascading” of value is a recurring theme in industrial biotechnology development (Van Dam, Klerk-Engles, Struick, & Rabbinge, 2005).

Table 12: Examples of biomass residues for different crops

Crops	Primary Residues	Secondary Residues	Residue
grains (wheat, corn, rice, barley, millet)	straw (stover)		1.0-2.0
		chaff (hulls, husks), bran, cobs	0.2-0.4
sugar cane		leaves and tops	0.3-0.6
		bagasse	0.3-0.4
tubers, roots (potato, cassava, beet)	foliage, tops		0.2-0.5
		peels	0.1-0.2
oil seeds	hulls		0.2-1.2
sunflower, olive,	foliage, stems		0.2-0.5
cocos, palm oil,	husks, fronts	shells	0.3-0.4
soy, rape,	peanut foliage	seed coat, shells	0.3-0.5
vegetables	leaves, stems etc.		0.2-0.5
		peelings, skin	0.1-0.2
fruits and nuts	seeds		
		fruit pulp, peelings	0.2-0.4

Sources: (Van Dam, Klerk-Engles, Struick, & Rabbinge, 2005), (Rosillo-Calle, De Groot, Hemstock, & Woods, 2007). A Residue ratio refers to ratio of dry matter weight to crop produced

The emphasis in this discussion is therefore on agricultural sources of biomass. Some examples of primary and secondary residues from agricultural crops are given in Table 12. There is considerable variation in the quantities available; in some cases, residues amount to only about 10-20% of the crop by weight, while in other cases the residues might actually be greater than the original crop. As shown in the table, grain crops tend to have the highest overall residue ratio, amounting to as much as double the crop weight; tubers have lower ratios. For this reason, utilization of straw from grains should be a much

higher priority in biomass utilization, and one of the papers in this volume addresses this largely untapped reservoir of biomass resources .

8.3 BIOMASS CONVERSION

There are many different routes for converting biomass to bio-energy and industrial products, involving various biological, chemical, and thermal processes; the major routes are depicted in Figure2. The conversion can either result in final products, or may provide building blocks for further processing. The routes are not always mutually exclusive, as there are some combinations of processes that can be considered as well. Furthermore, there are often multiple energy and non-energy products or services from a particular conversion route, some of which may or may not have reached commercial levels of supply and demand.

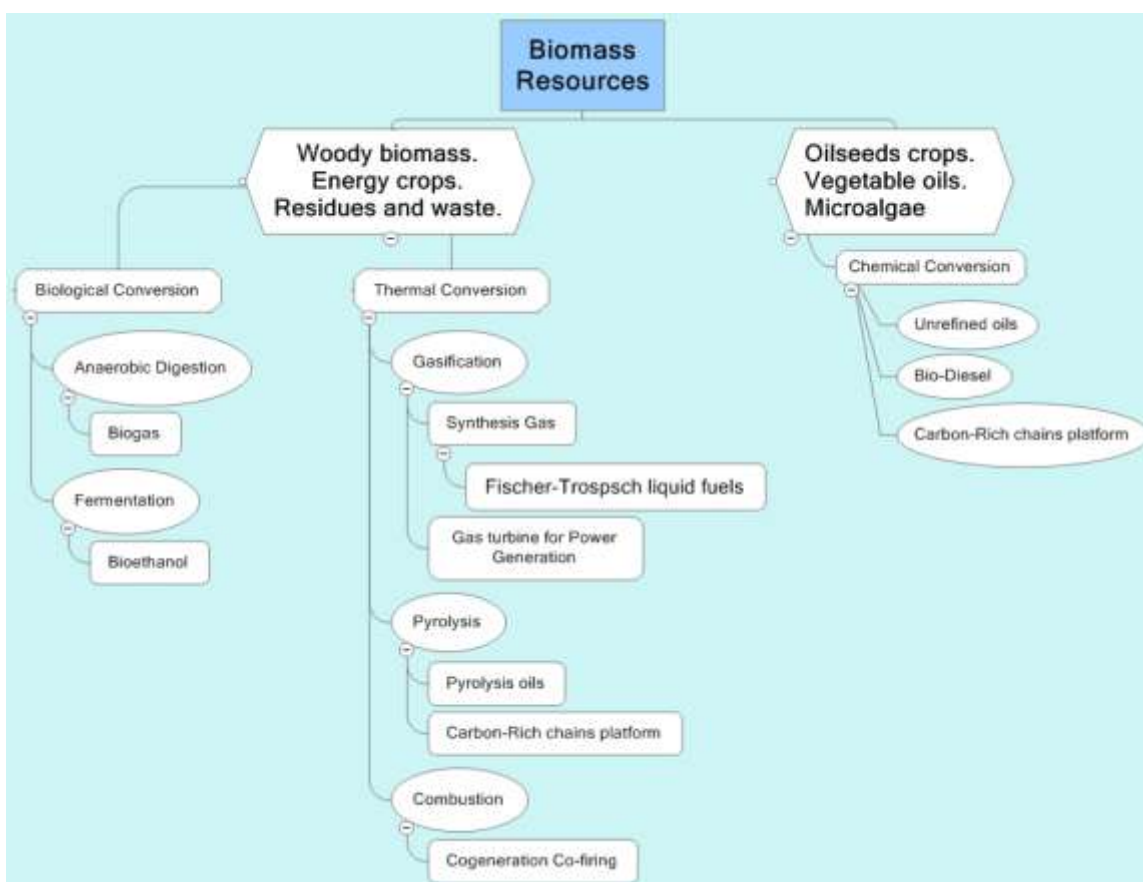


Figure 5: Conversion options for bioenergy and industrial biotechnology, biomass resources

There are some platforms that produce a wide range of both energy and industrial products, especially pyrolysis and the carbon-rich chains platforms. The carbon-rich chains platforms depicted in Figure 5 are being pursued in RD&D precisely because they offer the flexibility of making a wide range of industrial products at potentially large scales. Where more specific technical configurations are used, i.e. biorefineries or biomass platforms that are more customised and therefore more costly, the rationale will tend to be based on higher value-added products that justify the dedicated investments. It is important to note, however, that there are a wide variety of technical platforms at various scales, and these will need

to be matched to the needs of particular regions and markets. The role played in industrial development is to help in identifying and exploiting the most promising intersections between the technical options and market opportunities. Other than the sections below on pyrolysis and carbon-rich chains, the discussion below tends to emphasise energy conversion, since industrial product platforms are quite varied and it is difficult to generalise about them in this brief report.

8.4 BIOLOGICAL CONVERSION

Biological conversion is well-established, with the two main routes being fermentation and anaerobic digestion. Sugar and starch crops provide the main feedstocks for the process of fermentation, in which a catalyst is used to convert the sugars into an alcohol, more commonly known as bio-ethanol. Alternatively, any lignocellulosic source can be used as feedstock, by hydrolysing it, i.e. breaking it down into its components. The reaction is catalysed by enzymes or acids; acid hydrolysis offers the more mature conversion platform, but enzymatic hydrolysis appears to offer the best long-term option in terms of technical efficiency. Lignocellulosic conversion would greatly increase the supply of raw materials available for bio-ethanol production. The lignin residues could be used as fuel for the energy required and even providing surplus energy, resulting in significantly improved energy balances and resulting potential reductions in GHG emissions. Fermentation is the oldest platform for biological conversion and continues to constitute the most fundamental and mature area of biotechnology. For thousand of years, fermentation was important for preserving and processing food and beverages. Only in the last several decades, however, has biotechnology been used to bring to market a wide variety of fermentation-based products, including antibiotics, amino acids, organic acids, and various agro-industrial feedstocks and chemical substitutes. Anaerobic digestion uses micro-organisms to produce methane in a low oxygen environment. The waste stream from bio-ethanol production, known as vinasse, can be further converted through anaerobic digestion, creating a further step in a “cascade” of energy extraction processes. Methane gas can be used directly for cooking or heating, as is common in LAC, or it can be used for electricity and/or heat production. For transport applications, the biogas is used in compressed form, as is natural gas. Biogas can also be upgraded, i.e. cleaned of impurities and then fed into natural gas pipelines. Both bio-ethanol and biogas are commonly used in buses and other fleet vehicles in cities such as Stockholm and in the Midwestern region of the U.S.

8.5 COMBUSTION

Combustion is simply thermal processing, or burning of biomass, which in the simplest case is a furnace that burns biomass in a combustion chamber. Combustion technologies play a key role throughout the world, producing about 90% of the energy from biomass. Combustion technologies convert biomass fuels into several forms of useful energy e.g. hot water, steam and electricity. Commercial and industrial combustion plants can burn many types of biomass ranging from woody to MSW. The hot gases released as biomass fuel contains about 85% of the fuel’s potential energy. A biomass-fired boiler is a more adaptable technology that converts biomass to electricity, mechanical energy or heat. Biomass combustion facilities that generate electricity from steamdriven turbine generators have a conversion efficiency of 17 to 25%, but with cogeneration can increase this efficiency to almost 85%. Combustion technology research and development is aimed at increased fuel flexibility, lower emissions, increased efficiency, flue gas cleaning, reduced particulate formation, introducing multi-component and multi-phase systems, reducing NO_x/SO_x formation, improving safety and simplifying operations. Co-firing of biomass with fossil fuels, primarily coal or lignite, has considerable economic advantages, in that

existing installations for coal can be used, reducing capital investment. Biomass can be blended with coal in differing proportions, ranging from 2% to 25% or more biomass. Extensive tests show that biomass energy could provide, on average, about 15% of the total energy input with only minor technical modifications.

8.6 GASIFICATION

Gasification is another major alternative, currently one of the most important RD&D areas in biomass for power generation, as it is the main alternative to direct combustion. The importance of this technology relies in the fact that it can take advantage of advanced turbine designs and heat-recovery steam generators to achieve high energy efficiency. Gasification technology is not new; the process has been used for over 150 years, e.g. in the 1850s, much of London was illuminated by “town gas”, produced from the gasification of coal. Currently only gasification for heat production has reached commercial status. Gasification for electricity production is near commercialization, with over 90 installations and over 60 manufactures around the world (Kaltschmitt, Reinhardt, & Stelzer, 1997).

8.7 PYROLYSIS

The main advantage that pyrolysis offers over gasification is a wide range of products that can potentially be obtained, ranging from transportation fuel to chemical feedstock. The first commercial plants have recently come into operation. Any form of biomass can be used (over 100 different biomass types have been tested in labs around the world), but cellulose gives the highest yields at around 85-90% weight on dry feed. Liquid oils obtained from pyrolysis have been tested for short periods on gas turbines and engines with some initial success, but longterm data is still lacking . Pyrolysis of biomass generates three main energy products in different quantities: coke, oils and gases. Flash pyrolysis gives high oil yields, but still needs to overcome some technical problems needed to obtain pyrolytic oils. However, fast pyrolysis is one of the most recently emerging biomass technologies used to convert biomass feedstock into higher value products. Commercial interest in pyrolysis is related to the many energy and non-energy products than can potentially be obtained, particularly liquid fuels and solvents, and also the large number of chemicals (e.g. adhesives, organic chemicals, and flavouring) that offer companies good possibilities for increasing revenues.

8.8 CHEMICAL CONVERSION FROM OIL-BEARING CROPS

Oils derived from oilseeds and oil-bearing plants can be used directly in some applications, and can even be blended with petroleum diesel in limited amounts. Some restrictions are necessary depending on the engine type and also measures are needed to avoid solidification of the fuel in cold climates, since the various oils differ in their freezing points. Because the effect on engines varies with both engine type and the raw material used, there is still much debate on how much straight vegetable oil (SVO) can be blended with petroleum diesel without damaging the engine and/or its associated parts. Consequently, SVOs, as well as used cooking grease and other sources of raw oils, are generally used for local applications based on experience with specific applications, and are less likely to be internationally traded as a commodity for direct use. The refined versions of SVOs, on the other hand, can potentially be fully interchangeable with petroleum diesel, and are therefore preferred for international trade. Equivalently, the raw oils can be imported and the refining done locally, as is the case with petroleum.

The chemical refining process is referred to as trans-esterification, since it involves the transformation of one ester compound into another, a process that also transforms one alcohol into another. Glycerol—a viscous, colourless, odourless, and hygroscopic liquid—is a valuable by-product of the process, and is an important raw material for various pharmaceutical, industrial, and household products (Johnson & Rosillo-Calle, 2007).

An interesting option for the future is the production of bio-diesel from algae. The production of algae to harvest oil for bio-diesel has not yet been undertaken on a commercial scale, but feasibility studies have suggested high yields, as some algae have oil content greater than 50%. In addition to its projected high yield, algae-culture—unlike crop-based biofuels—is much less likely to conflict with food production, since it requires neither farmland nor fresh water. Some estimates suggest that the potential exists to supply total global vehicular fuel with bio-diesel, based on using the most efficient algae, which can generally be grown on algae ponds at wastewater treatment plants (Briggs, 2004). The dried remainder after bio-diesel production can be further reprocessed to make ethanol. The possibility to make both bio-diesel and bioethanol from the same feedstock could accelerate biofuels market expansion considerably.

8.9 CARBON-RICH CHAINS

Yet another set of options associated with these bio-chemical conversion processes relates to the creation of various carbon-rich compounds from glycerol and the fatty acids that comprise it. The carbon-rich chains form building blocks for a wide variety of industrial products that could potentially be produced, which are to some extent bio-degradable and/or the result of biological processes. Such platforms might be based on the carbon chains C2 and C3, which would in some respects lead to bio-refining processes that are analogous to the petroleum refining process (Van Dam, Klerk-Engles, Struick, & Rabbinge, 2005).

8.10 BIO-REFINERIES

Raw materials used in the production of bio-based products are produced in agriculture, forestry and microbial systems. The content of the material undergoes treatment and processing in a refinery to convert it, similar to the petroleum. While petroleum is obtained by extraction, biomass already exists as a product that can then be modified within the actual process, to optimally adapt the results so as to obtain particular target product(s) (Kamm & Kamm, 2004). This is contained within the technology of the bio-refinery whose objective is to convert the raw material into intermediate and final useful products. The basic principles of the biorefinery are shown in Figure3. A biorefinery can utilise different feedstocks, can incorporate many different processes, and can result in many different end products. The exact configuration of a particular biorefinery will depend on market prices of inputs, demand for final products, access to the appropriate technologies, availability of financing, operational knowledge, and supporting policies and institutions.

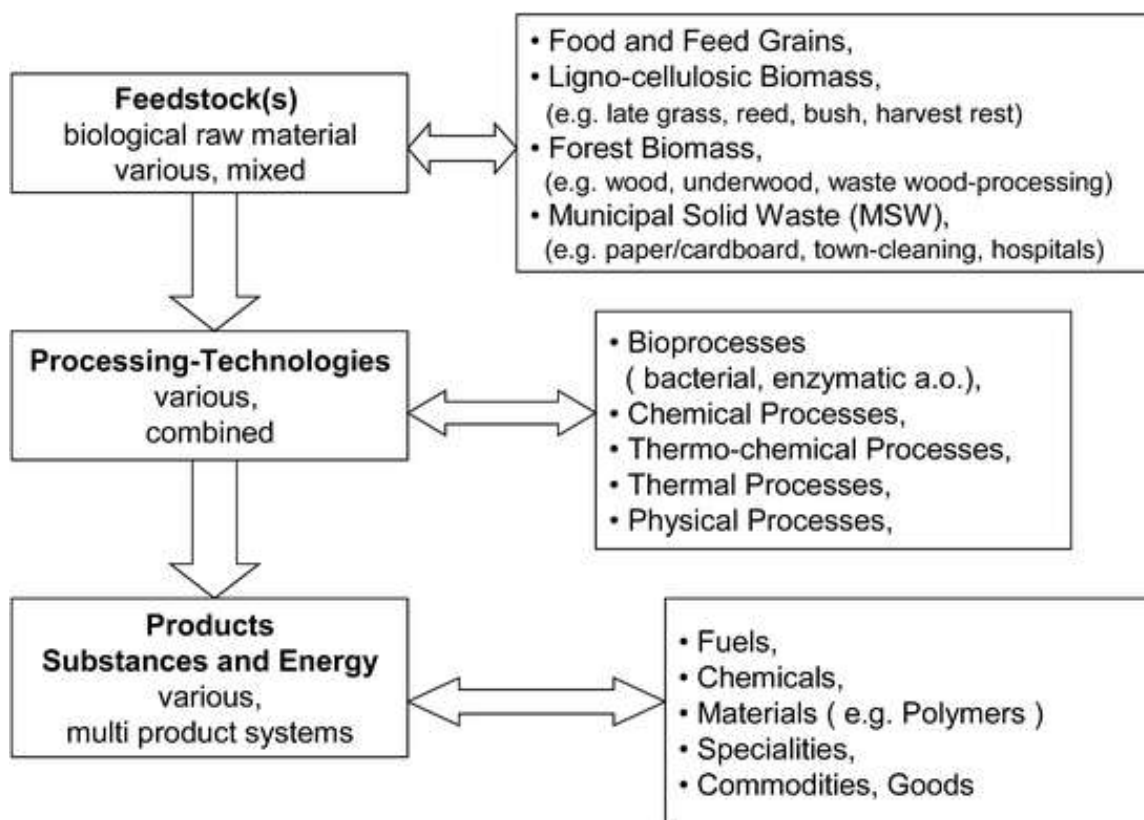


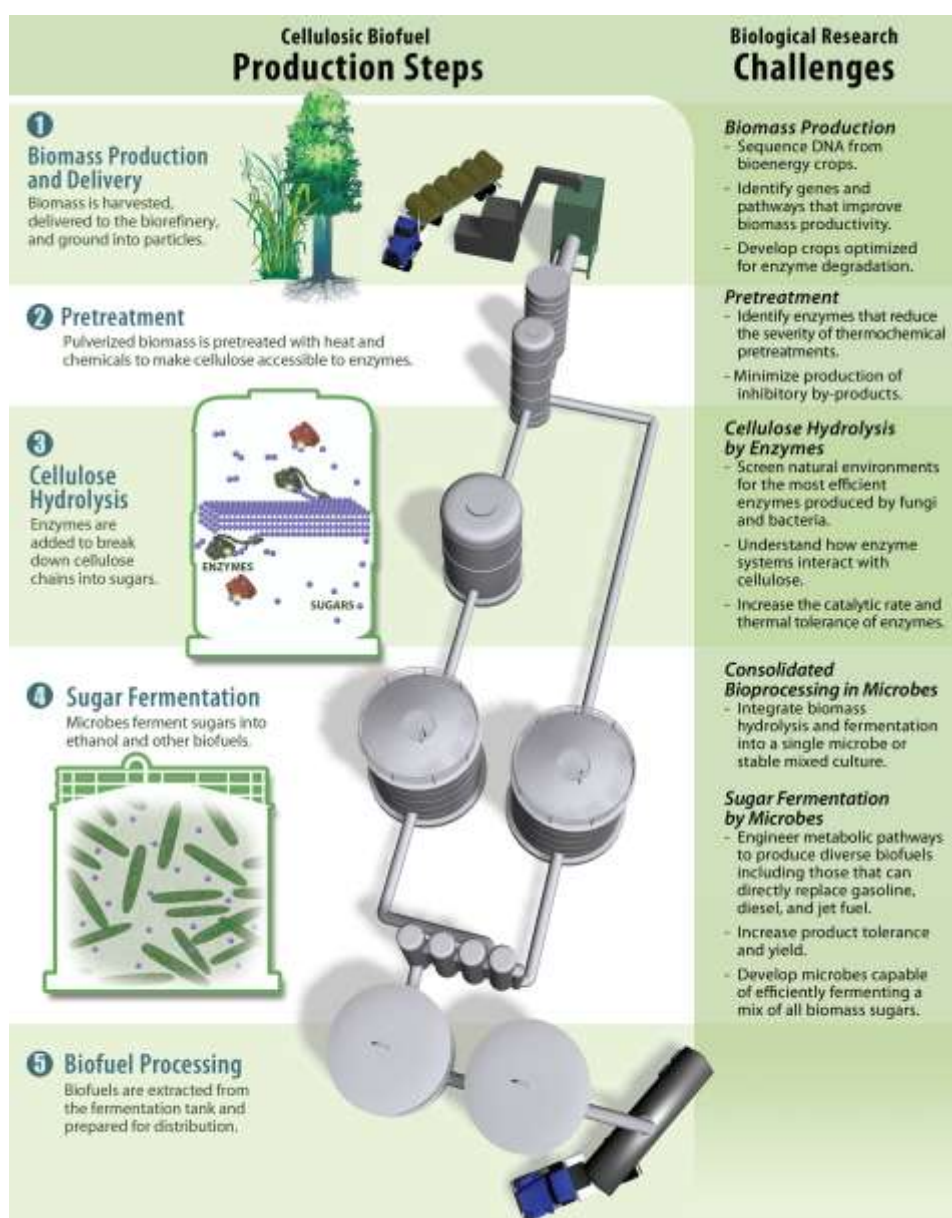
Figure 6. Basic principles of a biorefinery

The range of bio-based products is not only as replacement products for those produced in petroleum refineries, but also products not accessible to these refineries. The potential range of products is extremely broad once the essential biomass building blocks are available. Innovative technologies are required to convert the feedstock to useful substances, products and energy. Further research and development are necessary to increase understanding, improve agricultural, processing and efficiency of these systems and to create the policy and markets to support this technology.

8.11 CELLULOSIC BIOFUEL PRODUCTION STEPS AND BIOLOGICAL RESEARCH CHALLENGES.

Although cellulosic ethanol production has been demonstrated on a pilot level, developing a cost-effective, commercial-scale cellulosic biofuel industry will require transformational science to significantly streamline current production processes. Woodchips, grasses, cornstalks, and other cellulosic biomass are widely abundant but more difficult to break down into sugars than sugar cane. Biological research is key to accelerating the deconstruction of cellulosic biomass into sugars that can be converted to biofuels. The Department of Energy (DOE, USA) Office of Science continues to play a major role in inspiring, supporting, and guiding the biotechnology revolution over the past 25 years. The DOE Genomic Science Program is advancing a new generation of research focused on achieving whole-systems understanding for biology. This program is bringing together scientists in diverse fields to understand the complex biology underlying solutions to DOE missions in energy production, environmental remediation, and climate change science. New interdisciplinary research communities are

emerging, as are knowledgebases and scientific and computational resources critical to advancing large-scale, genome-based biology. To focus the most advanced biotechnology-based resources on the biological challenges of biofuel production, DOE established three Bioenergy Research Centers (BRCs) in September 2007 (DOE, 2010). Each center is pursuing the basic research underlying a range of high-risk, high-return biological solutions for bioenergy applications. Advances resulting from the BRCs will provide the knowledge needed to develop new biobased products, methods, and tools that the emerging biofuel industry can use. Then, the scientific community in Latin America may take advantage of these centers and for other fundamental genomic research critical to the biofuel industry. By doing that LAC would develop automated, high-throughput analysis pipelines that will accelerate scientific discovery for biologybased biofuel research.



This figure depicts some key processing steps in an innovative conception of a future large-scale facility for transforming cellulosic biomass (plant fibers) into biofuels. Three areas where focused biological research can lead to much lower costs and increased productivity include developing crops dedicated to biofuel production (see step1), engineering enzymes that deconstruct cellulosic biomass (see steps 2 and 3), and engineering microbes and developing new microbialenzyme systems for industrial-scale conversion of biomass sugars into ethanol and other biofuels or bioproducts (see step 4). Biological research challenges associated with each production step are summarized in the right portion of the figure. Source: U.S. Department of Energy Office of Science. Bioenergy Research Centers: An overview of the Science, 2009.

9. CLEAN DEVELOPMENT MECHANISM

The Clean Development Mechanism (CDM) is currently the only formal avenue for developing countries to obtain support for climate mitigation efforts from Annex 1 parties. In principle, almost any GHG-reducing measure or project in a non-Annex 1 signatory country is eligible to qualify for credits under the CDM. In practice, of course, the application process itself requires time and resources, which can, in turn, impact the type and location of projects submitted and approved. A great deal of detailed analysis is required in order to document the baseline GHG emissions and project boundary to determine the emissions reductions that will be “additional” to those that would have occurred in the absence of the CDM project. The major sources of GHGs in the developing world are:

- Stationary combustion of fossil fuels, mostly for electricity generation;
- Non-stationary combustion of fossil fuels (e.g. for transport);
- Deforestation;
- Agriculture and land use (e.g. methane emissions from animals, landfills, or decaying agricultural or forest residues);
- Industrial processes

Availability of technological solutions is one issue, particularly for developing countries, and investments in infrastructure, physical and human capital is another. Yet, the concept deserves further analysis and could address many factors that are relevant and have a positive impact on the economy and society in developing countries. When Annex 1 countries are looking for host countries or when project developers in developing countries are seeking support, the host country’s infrastructure, administrative apparatus and institutional capacity were all important factors. The larger developing countries thus have clear advantages, especially since the state-to-state nature of the UNFCCC process means that larger countries simply have more to offer. In terms of expected annual emission reductions at the end of the commitment period (2012), three countries account for over two-thirds of the total credits: Brazil, China, and India . Transaction costs also make certain types of projects (and certain countries) less attractive for CDM, and consequently a separate category with streamlined procedures were established for small-scale projects, which are currently defined as (UNFCCC, 2010):

- renewable energy projects up to 15 megawatts maximum capacity (or an appropriate equivalent);
- energy efficiency improvements that reduce energy consumption, up to the 15 gigawatt/hours per year; or other projects that reduce anthropogenic emissions and directly emit less than 15 kt CO₂ equivalent annually.

The streamlined procedures appear to have been useful for some types of energy efficiency and renewable energy projects. In the case of biomass and bio-based products, they appear to be less useful because the definition is based on the fact that many projects deal with one major output, whereas

biotech deals with many simultaneously. Best-practice guidelines would facilitate technical convergence and reduce the transaction costs associated with matching technical options to different physical and socio-economic conditions. In some cases, it will be appropriate to identify key products that can offer a “market opener,” for certain regions, based on their comparative advantage. In other cases, the design and scale of facilities might be sketched in general terms, but with the possibility to add some regional content. Bio-refinery platforms might be established from which local variations can optimise for varying conditions.

The CDM can be applied to solid waste management activities and can help to overcome some of the development barriers. The revenues from the sale of emissions credits can contribute to the advancement of environmentally sound waste management practices. The waste sector is now well represented amongst the registered CDM projects. As of October 2009, 18% of the 1834 registered CDM projects are waste sector projects. These include solid waste project activities, (landfill gas recovery, composting, and incineration) as well as methane avoidance technologies (composting, anaerobic and aerobic treatment) for waste water, agricultural and forestry waste. 138 of the 407 registered waste projects are municipal solid waste projects (herein after referred to as “solid waste” projects). The currently registered waste projects are expected to deliver 209 million emission credits by the end of 2012. (One carbon credit corresponds to an emission reduction of one tonne of CO₂ equivalent.) (CD4CDM CDM Pipeline – November 2009)

The United Nations has set up a governing body to oversee the CDM (the CDM Executive Board (CDM EB)). This body has established the procedure for project approvals and issuing credits. In order to submit a project for registration, a project design document (PDD) must be prepared in accordance with a reference baseline and monitoring methodology that has been approved by the CDM EB. To date, the CDM EB has approved 17 methodologies which apply to waste sector activities, (6 large-scale, 3 consolidated and 8 small-scale methodologies) (UNFCCC, 2010).

9.1 TECHNOLOGY DIVERSIFICATION

Nearly 90% of the registered solid waste projects are related to landfill gas flaring and recovery. Thanks to strong emission reduction potential, particularly with regard to the potent GHG methane, coupled with relatively low abatement costs, these projects have attracted attention from a broad range of project developers in comparison with other technologies.

By contrast, only a limited number of large scale projects have been registered involving advanced MSW treatment technologies such as large scale composting, gasification, anaerobic digestion or refuse derived fuel (RDF) processing and thermal treatment without incineration. Some of the reasons for this are:

- As most of these projects concern new installations, they require significant planning and stakeholder approval;
- Advanced technologies are necessarily more complex and require higher capital and operating costs than landfilling and small-scale composting;
- There is a lack of management capable of handling these technologies within these communities;
- The selected technology must be adapted to the local waste characteristics;
- It is essential to have established markets for by-products (compost, recovered material and energy).

In addition, all of these causes are compounded by uncertainty on the future of carbon finance beyond the first compliance period of the Kyoto Protocol (the end of 2012).

9.2 GEOGRAPHICAL DISTRIBUTION

In common with other industrial sectors, CDM projects in the waste management sector are so far unevenly distributed and have generally not yet benefited the Least Developed Countries (LDCs).

Solid waste CDM projects in the pipeline are distributed mostly between Asia/Pacific and Latin America; respectively 44% and 42% of the total (October 2009). In Asia, the highest number of projects is in China with India following in second position. In Latin America, Brazil and Mexico represent the majority share. Other regions are poorly represented. For example, Africa and the Middle East account for just 7% and 5% of the total number of projects, respectively.

This subject of geographic distribution of CDM is receiving much attention from the CDM EB and a number of international stakeholders. Efforts must continue to achieve a better distribution of projects and to improve access to CDM within these host countries.

Concerns with the approval process

Although significant progress has been made on the CDM since its inception, there is still room for improvement in the current system. A number of issues have been raised with regard to the CDM approval process and delays in obtaining registration or credits.

Some of the key barriers limiting efficiency and causing delays in the CDM approval process are:

- Lack of available Designated Operational Entities (DOEs) resource for the validations and verifications, due to the significant number of projects being initiated;
- Constantly evolving rules and guidance, giving rise to diverging interpretations of methodology requirements amongst the project participants, the DOEs and the CDM EB
- The application time for evolving methodologies and guidance is not always compatible with the timeline for advancing through the different approval steps;
- Increasing CDM EB scrutiny of projects following their submission for registration or credit issuance. The CDM EB has requested a significant number of reviews of projects which have been validated or verified;
- Limited access for the Project Participants to communicate directly with the CDM EB on decisions, requests for review, or clarifications. It is necessary to wait for official comments from the CDM EB and often their exact concerns are unclear from the provided text of reviews or decisions.

The CDM EB has been working on a number of initiatives intended to improve process efficiency while maintaining its integrity.

Conclusions

Currently there is not a regional program leading WTE. Many countries in Latin America are, for the first time, beginning to explore the use of WTE plants as part of their integrated solid waste management plans. In Europe, WTE shows some advantages: the total energy recuperation rate can be relatively high and incineration, as a process, results in a large waste volume reduction (80-95 per cent), which greatly reduces the space required for disposal. Also, if proper emission reduction measures are taken, incineration is a clean means of waste processing. It is, however, an expensive option, both in terms of investment and operation. Investment costs of a modern 1,200 ton per day incineration plant in Europe are in the order of US\$ 300-400 million, while the processing costs are about US\$ 100-150/ton—half of which are capital costs. Furthermore, incineration is only applicable when a number of overall criteria are fulfilled:

- Existence of a mature and well-functioning waste collection and management system for a number of years.
- A minimum and stable supply of combustible waste (at least 50,000 tons/year).
- A minimum average lower calorific value (at least 7 MJ/kg, never below 6 MJ/kg).
- A community that is willing to absorb the increased treatment cost.
- Skilled staff who can be recruited and maintained.
- Solid waste disposal at controlled and well-operated landfills.
- A stable planning environment of the community (planning horizon at least 15 years).

In this context, LAC's do not appear as promising environments for the WTE industry. A significant percentage of the waste generated ends up in uncontrolled landfills or illegal dumpsites. This situation presents obvious environmental and health concerns. By implementing proven waste management technologies, LAC's can improve the public health and environment, while also achieving reduced GHG emissions. Unfortunately, despite the major benefits that can be realized from improvements in the waste management infrastructure in developing countries, financial and institutional barriers often inhibit their implementation.

In the case of rural areas, poor people need access to modern energy but at reasonable cost. Cooking by using basic energy technology (three stone fires, inefficient cooking stoves) requires further analysis not only in sourcing of renewable energy but also finding a reliable mechanism to deliver energy to a household. WTE needs to overcome diverse barriers to delivery in rural areas where electric infrastructure is not always considered a high priority for local governments. Currently, there are a number of people relying on the traditional use of biomass as the primary fuel for cooking. However, biogas has been considered as household fuel in rural areas, and a biodigester seems to be the cheaper mechanism to produce energy in small communities. In fact, biogas has been promoted by local NGO's in various LAC's. However, it is important to improve education and technical training to poor people so they can keep their biodigester running after local NGO's make the first step. It is common that a biodigester works properly while technicians from the NGO still available in the rural community, but afterwards becomes a problem for local people. In the region, Red Biolac is moving forward not only to improve biogas production but also to promote knowledge transfer to local people.

In the last decade, Latin American countries have been working on other biomass sources (agricultural waste, animal wastes, MSW, natural growth forests, and water-based biomass such as micro-algae) to

innovate around bio-energy and industrial products, involving various biological, chemical, and thermal processes. The heterogeneity of biomass along with the many potential conversion paths and market applications has high potential. However, the introduction and expansion of biotechnologies within the different industrial sectors can only be achieved when the institutional setting in a given country includes the appropriate policies, socio-economic frameworks and legal mechanisms. LAC's private sector development initiatives—including investment, technology acquisition and adaptation programmes—must promote programs at local and regional levels.

In this context, Latin America is actively looking out, and seeking to apply, the advancements made by U.S./Europe waste-to-energy companies in the last two decades. Waste-to-energy companies have been interested in new business opportunities for their systems in overseas markets. However, there are many obstacles to overcome in marketing technology, waste disposal services and energy legislation. Policies must likewise promote the formal creation of a solid waste disposal sector—alongside currently existing water and sanitation sectors—as well as the restructuring of solid waste management, establishment of laws for the new sector, and strengthening of oversight, regulation, municipal management, institutional coordination, civil society participation and sustainability, and private initiative.

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10. ANNEX

SUCCESS STORIES

Around the world, there are numerous examples of successful bioenergy projects, including industrial Combined Heat and Power (CHP) installations, biogas production and utilization, carbonization, densification and gasification.

This chapter offers a brief description of a small selection of such success stories. The selection by no means covers the full spectrum of technological options, biomass resources or relevant sectors, nor does it touch upon all the different aspects of each project. However, it does show examples of successful applications that may have a great potential for replication in many countries around the world.

A.1 RICE HUSK-FIRED CHP IN THE BRAZILIAN RICE INDUSTRY

Background

Rice is one of the world's most important food crops. It is produced in more than 100 countries on all continents. Total world production was more than 600 million tons in 2006, about half of which was produced in China (29 per cent) and India (22 per cent). Processing of rice results in the production of considerable residues, in particular rice husk. Each ton of rice produced, results in the production of about 0.22 tons of husks. These husks are relatively dry, and, despite their high ash content, have a good heating value. Some husks are used for producing energy for drying purposes, or as an additive for building materials. However, very often a large part of the husks are not used at all and are disposed of through dumping or uncontrolled combustion. With an annual rice production of about 11 million tons, Brazil ranks amongst the top 10 rice-producing countries [62]. One of the country's largest rice processors is CAMIL Itaquí, located in the state of Rio Grande do Sul. In the year 2001, the company installed a rice husk-fired CHP installation to cover their need for process heat and electricity.

Technology

Over the years, rice husk has increasingly been used as a fuel for Combined Heat and Power (CHP) installations. In such installations, production of heat for industrial processes or district heating is fully integrated with electricity production. This means that the heat is either produced as a by-product of electricity production, or that the electricity is produced at times when heat demand is low. The CHP plant at CAMIL Itaquí is a conventional condensing steam power plant with a capacity of 4.2 MWe, which is more than sufficient to cover the company's own electricity demand of 3.5 MWe. The excess electricity is supplied to the national grid. The installation also supplies process heat for rice production, with a capacity of up to 7.8 MWth. Under nominal operational conditions, the installation consumes 7.5 tons of rice husks per hour. Although the CHP installation started in 2001, it was not until 2005 that the company was legally allowed to supply electricity to the grid. Since then, the installation has been operating at full load. Around 90 per cent of the husks that are produced at the rice mill are now used for electricity generation. In 2007, the unit generated nearly 27,000 MWhe, of which about 23 per cent was supplied to the grid.

Rio Grande do Sul state is one of the two states in Brazil that use coal fired thermal power plants complementing the energy demand in the integrated south Brazilian electrical grid. By the replacement of power from the grid and by supply of electricity to the grid, carbon from the coal combustion in

electricity plants is avoided. Apart from this, the use of rice husk for power generation prevents the dumping of residual rice husk, which was the common method of disposal prior to the implementation of the project. As such, the implementation of the project avoids emissions of methane from decomposing rice husk. The project has successfully applied for CDM registration. In the period of July 2001 to December 2006, the emission of about 260,000 tons of CO₂ equivalents has been avoided. The generated CER's have been sold to the Dutch company Bioheat International, generating additional income for the project.

Other benefits

The plant has a demonstration function in the region and attracts the interest of many rice mill owners. Capacity building for operation and maintenance of the plant is also being promoted. Specialized services companies are introduced and act as carriers of know-how; carrying out training of plant operators, specialized maintenance and tuning of the equipment. Knowledge is transferred in the region, thereby developing the use of this technology in Brazil.

Success factors

Specific success factors are the following:

Involvement of a viable industry, with a capacity to invest;

Application of proven technology;

Additional income from CDM, which was possible because of the large enough scale of the installation and the portfolio approach.

A.2 GEM TO MANAGE BESG'S WASTE-TO-ENERGY OPERATIONS IN BRAZIL

General Environmental Management (GEM) has entered into a Letter of Intent (LOI) to execute formal agreements with Bio-Energy Solutions Group (BESG) to manage their waste-to-energy operations in Pernambuco, Brazil, including the collection and processing of municipal solid waste and subsequent conversion to alternative energy. The management agreement will have a term of 15 years.

BESG has contracts for 34 towns in the state of Pernambuco, Brazil, with additional towns requesting contracts.

BESG claims that it offers an alternative to the traditional landfill approach by reducing municipal solid waste using natural processes, extracting marketable recyclates from the waste input stream, and enabling the residual biomass to be used as feedstock for generating renewable energy in an environmental friendly manner.

Timothy Koziol, CEO of GEM, said: "This waste-to-energy (WTE) project is enormous in scope, and GEM will have to consider the best use of resources to accomplish the management of this project, but we are pleased to have been chosen and look forward to making this project the main focus of our business activities. GEM will therefore not complete the financing and acquisition of California Living Waters.

"The formal purchase agreements called for GEM to make a payment to United States Environmental Response on June 30, 2010, which we will not make. Although we believe in the opportunity to build a strong and profitable company with Southern California Waste Water as a foundational entity, we will

change our focus to the WTE arena and build an international enterprise with BESG, beginning with Brazil.”

The initial installation of a facility in the state of Pernambuco, Brazil is expected to serve primarily organic materials from towns in two states. It is anticipated that 4,900,000 tons per year of feedstock from over 368 municipalities will be managed by this initial facility by the end of 2011.

A.3 BIOGAS FROM WASTEWATER TREATMENT IN THE COSTA RICAN COFFEE INDUSTRY

Background

The coffee sector has always been an important economic sector in Costa Rica. In the early 1990s there were almost 100 coffee processing plants, processing approximately 875,000 tons of coffee beans per year. Coffee mills generate large amounts of waste water, containing high concentrations of organic compounds. A common waste disposal method is discharging in the rivers, provoking enormous pollution, threatening organic life and causing a very bad smell. In 1992, the Costa Rican government and the coffee sector agreed to substantially reduce the pollution caused by wastewater discharging. The stringent environmental legislation required the coffee processing companies to apply wastewater treatment prior to discharging. Anaerobic treatment was identified as one of the most appropriate technologies for reducing the organic load of the wastewater. Apart from an effective biological treatment, anaerobic treatment results in the production of biogas, a clean renewable fuel that can be used to generate electricity and process heat. After a successful pilot project at one of the larger coffee processing companies in 1996, several other large companies decided to install anaerobic wastewater treatment systems at their plants. By 2000, in total nine systems have been successfully installed.

Technology

The system that was implemented at the coffee companies was based on the Upstream Anaerobic Sludge Bed (UASB) process, which had been developed in the late 1970s at the Wageningen Agricultural University in the Netherlands.

The UASB reactor is basically a concrete basin, with a layer of methane-producing bacteria in a sludge blanket on the bottom. The wastewater is pretreated (screened, brought to the right temperature and pH) and enters the reactor from the bottom. On its way upward, it passes through the sludge blanket, where most of the organic compounds are removed by the bacteria. Part of the overflowing, treated waste water is mixed with the “raw” waste water and re-enters the reactor, while another part can be safely discharged. The biogas that is produced by the bacteria in the sludge blanket goes upward, is captured in the reactor cover, and led to the gas application. In all plants, the biogas is used for the production of energy. In some cases the gas was burned for heat production for drying purposes. In three cases, CHP units were installed that produce electricity (typically 200-300 kWe) and process heat for the coffee factory. The UASB process is modular based; each module of 250 m³ is able to process 2,500-3,000 kg COD₂₆ per day and produces 800 m³ of biogas (75 per cent CH₄) per day. This modular concept allows for simplified design procedures and low-cost production, facilitating rapid project implementation. The

installations have reactor volumes in the range of 500 to 1,500 m³, with biogas production between 1,000 and 4,000 m³/day

Success factors

Critical success factors are the following :

The stringent environmental legislation that was introduced in the early 1990s was a prerequisite for the introduction of wastewater treatment in Costa Rica.

The coffee industry was obligated to adopt water treatment measures, and the UASB system was the most viable system available.

The technology was well-designed for the application. It was flexible with respect to varying organic contents. Modular design and choice of construction materials made implementation easy, at modest investment costs. At the same time, its complexity did not surpass that of other technologies used in the coffee plants.

The circumstances for producing power for the electricity grid were favorable, and the feed-in tariffs were high.

The dramatic decrease of coffee prices in the early 2000s has taken its toll among coffee processors in Costa Rica, and a number of companies have since then gone bankrupt. In addition, the world market situation has prevented other coffee processing countries to introduce more strict environmental legislation, in order not to damage their coffee industries. In effect this has prevented the more widespread implementation of the technology.

A.4 CNFL TO BEGIN WASTE-TO-ENERGY PLANT OPS 1H02 - COSTA RICA

Costa Rican state power distributor Compania Nacional de Fuerza y Luz (CNFL) expects to begin operations at its US\$3.6mn Rio Azul waste-to-energy plant in capital San Jose in 1H02, a CNFL official told BNamericas.

"We expect to finalize contractual details by year end and begin the plant's construction 1H02," the official said. The CNFL had announced the plant would be operational by end-2012

Earlier this year, the CNFL selected UK-based Saret to operate the plant under a BOO contract, which entails providing the equipment and operating the facility. The plant will have a 3MW generating capacity, some 30GWh per year. CNFL will buy all power from the plant.

Local waste management company WPP Continental operates the 27-year old Rio Azul landfill, which takes in some 1,200 tonnes per day of waste. Water from the waste-to-energy plant will be treated before release into the Azul river.

A.5 WPP CONTINENTAL TO DEVELOP WASTE-TO-ENERGY PROJECT IN ALAJUELA, COSTA RICA

Costa Rican waste management firm WPP Continental is waiting for the UN Framework Convention on Climate Change (UNFCCC) to approve a waste-to-energy project as a clean development mechanism (CDM), WPP Continental operations manager Christian Montero told BNamericas.

The project will be carried out at the Los Mangos landfill in Alajuela province and will generate energy from methane gas.

"Of the gas produced when organic waste decomposes, 50% is carbon dioxide and the other 50% is methane, which is also a combustion gas that can generate electricity," Montero said.

The project is already designed and only lacks the UN certification to begin construction. Once that comes through, it is easier to obtain financial support from different organizations, according to Montero.

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A.6 WASTE-TO-ENERGY COMPANY W2 ENERGY MAKES DEALS IN PANAMA AND COLOMBIA

Waste-to-energy Company, W2 Energy Inc., has announced that the company's initial negotiations for waste-to-energy plants in South America were successful, with new deals in Panama and Colombia.

W2 Energy manufactures waste-to-energy plants that can turn solid waste into usable fuel and electricity. A four-ton plant can generate sulfur-free diesel and electricity using up to two million tires a year as feedstock. All South American countries have problems with tire disposal. The system can also be fed with municipal solid waste, agricultural waste, human and animal waste, tires and plastics, and medical waste. The closed-loop system does not produce any emissions and can generate carbon credits from energy generation. Each waste-to-energy plant costs \$2,700,000.

The Panama deal involves a joint venture with R&J Howell, a company already established in the country. Under the joint venture, W2 Energy will supply two four-ton plants. The joint venture is also open to the possibilities of opening other waste-to-energy plants in other Central American countries.

A memorandum of understanding (MOU) was signed in Colombia for a 40-ton plant, and the possibility of several four-ton plants in smaller communities. W2's 40-ton plant can generate up to 100 barrels of diesel a day and 1.5 megawatts (MW) of electricity an hour.

W2 Energy Inc. designs biomass-to-energy plants that convert feedstock into syngas, using a patented plasma-based reactor technology.

A.7 COYHAIQUE, CAPITAL CITY OF THE AYSÉN REGION IN CHILE'S SOUTHERN PATAGONIA.

Environmental Evaluation of Waste Management Alternatives by LCA in Chile Coyhaique, capital city of the Aysén Region in Chile's southern Patagonia, has approx. 45,450 inhabitants, concentrating about 50% of the total regional population (INE 2002). Currently, approx. 14,000 Mg/year of municipal solid waste (MSW) is generated in Coyhaique, resulting in a per capita generation of 0.84 kg/day, characterized mainly by its organic content of 51% (SA 2008). These wastes are deposited in a landfill, which has become saturated in recent years.

Life Cycle Analysis (LCA) has been internationally used for comparing environmental impacts associated with different management scenarios of municipal solid waste (MSW). Today, there are few studies in process for the city of Coyhaique, in the Chilean Patagonia, in order to identify the most environmentally suitable alternative to manage them: MSW direct landfill disposal (Scenario 0), direct disposal in sanitary landfill and landfill gas recovery for energy production (Scenario 1), and biogas recovery through a digester, for the energy production (Scenario 2). Results show that Scenario 0 presents the greatest negative impacts, whereas Scenario 1 is the major positive impacts foreseen in the indicators evaluated, making it the most environmentally friendly alternative.

A.8 SANTIAGO-CHILE

Chile passed the Renewable Electricity Law in 2008 which states that a minimum of 5% of all electricity sources must come from various renewable energy sources by 2010, there are few examples on new technologies, especially on WTE.

After reviewing different technologies and the advantages and disadvantages of each one the conclusion was that the most appropriate technology for Santiago is the mass burn plant. The current mass burn systems are very reliable and have been running successfully for a long time, thus are widely considered as a proven technology. In this category, the Martin Grate technology, with a capacity of 1,200 metric tons/day and an energy output of 600 Kwh per ton to be sold commercially, was selected. Waste-to-energy facilities save valuable landfill space and produce clean and renewable energy through the combustion of MSW in specially designed power plants which are equipped with state-of-the-art pollution control technologies. The WTE facility that is proposed for Santiago will use a total space of 9 hectares. Trash volume is reduced by 90% and the remaining residue consistently meets strict EPA standards allowing reuse or disposal in landfills. The project evaluation, using the criteria of Net Present Value (NPV), demonstrates that a WTE Plant for Santiago, with a capacity of 1,200 ton/day, would be able to generate enough income to have a positive NPV. In other words, the project generates more economic value than the cost of its investment. With a 7%/year real discount rate, the net income would be US\$ 13 million. The project is viable without requiring any substantial additional government support beyond the current municipal transfers. If the Central Government were to fully finance the investment costs of the Plant, the WTE plant would end up being a less costly alternative for Municipalities than landfills. Santiago's current MSW management is based on short-term solutions that are not sustainable. In the coming decades Santiago is going to run out of landfill space. The implementation of WTE indicates that could be an environmental and economic solution to MSW disposal in Santiago. It is believed that Waste-to-Energy is a viable answer to address Santiago's long term solid waste management needs.

A.9 BRAVO ENERGY IN CHILE

Bravo Energy is a leader in waste to energy resource recovery in Latin America, a position gained through know-how and experience operating waste to energy processing facilities in strategic markets located throughout Latin America. Bravo Energy is a leader in waste to energy resource recovery in Latin America, a position gained through know-how and experience operating waste to energy processing facilities in strategic markets located throughout Latin America.

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A.10 FLOKA WASTE TO ENERGY (W2E) FACILITY, CHILE

Technical Summary

In the south of Chile, in the past 10 years there has been an important raise in waste generation due to rapid growth in salmon farming industry (650.000 ton final product in 2008), and other associated economic activities. Last year, ISA virus contamination, together with a poor waste management, implicated an 80% drop in production level. Presently, salmon industry and Chilean government are working hard in industry reactivation, which is projected to be fully recovered by 2015. These efforts consider new sanitary designs that allow sustainable growth and development of salmon farming industry. Before ISA crisis, an average processing plant generated around 20.000 m³/day of wastewater and treatment sludge which mainly were sent to anaerobic lagoons and aerobic wastewater treatment plants. Also, during 2008 around 50.000 ton of mortality were generated, and managed poorly through final disposal in old poor landfills. Floka W2E facility Project considers reception of wastewater along with sludge a solid wastes and treating them to obtain energy from them. The project also considers reception and treatment of other industrial wastes generated in the area (cow and pork growth and slaughter; diary; shellfish) that are not managed nor treated in a sustainable manner.

A conservative preliminary evaluation was carried out considering only 10% of total wastes generated. "Floka W2E Facility" is designed to receive and treat a waste mix through biodigestion (humid fermentation) technology to produce biogas. A part of this biogas is used to maintain reactor operation temperature and the rest is used to produce electric energy. For this stage, 3 WAUKESHA APG 1000 gen-sets were considered to achieve an installed generation capacity of 3 MW. This equipment is considered to have heat recovery units to improve their total efficiency thus reducing total biogas used in heating reactors.

Project is located close to electric grid which makes it feasible for energy commercialization, land considered accounts for environmental permits and methane generation potential tests were carried out for wastes considered. Capital Costs:USD\$ 9.500.000

A.11 BIO-CANCUN PROJECT: WTE PLANT CANCUN, MEXICO

Secretaria de Ambiente y Recursos Naturales (SEMARNAT, Mexico)
Environment Canada

In 2009, Canada and Mexico decided to work together to implement a waste-to-energy project to divert organic matter from landfill sites. In 2010, SEMARNAT and EC held an introductory workshop in Cancun to present the project to local authorities: the State of Quintana Roo and the City of Benito Juarez

Objectives

Build a bio-digester for treatment and use of OFMSW
Implement a continuous process to divert OFMSW from landfill
Generate power from biogas and fertilizers as a by-product.
Serve as a test for similar Waste-to-energy systems to be implemented throughout Mexico (Acapulco, Puerto Vallarta..)
Support technology transfer and deployment of clean technologies

Rationale for Bio-Digestion

Guaranteed Supply: Organic Material available from all-inclusive resorts
Capacity: 2 existing landfills sites at capacity
Land-use: Development of a new site would require 45-65 ha of land. 4-5 for a bio-digester.
Water contamination: Water table is high and huge threat of contamination by leachates
Complementary Energy supply: Power to run the Bio-digester would come from its own operation.
Excess will be send back to the power grid.
Sustainable Waste Management: Local Authorities will implement a sorting/recycling program to separate OM from other SMW.