Waste management in Laguna Province Philippines

"Integrated Resource Management in Asian Cities: the Urban NEXUS"

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LIST OF ACRONYMS

BMZ	German Federal Ministry for Economic Cooperation and Development
BOD	Biological Oxygen Demand
C/MSWMB	City/Municipal Solid Waste Management Board
CAPEX	Capital Expenses
CCDMRF	Centralized Clustered District MRF's
CENRO	Community Environment and Natural Resources Office
CH_4	Methane
CHP	Combined Heat and Power plant
CO_2	Carbon Dioxide
COD	Chemical Oxygen Demand
CV	Calorific Value
DAMP®	Defined Aerobic Mixing Process
DAO	DENR Administrative Order
DENR	Department of Environment and Natural Resources
DO	Dissolved Oxygen
DS	Dry Substance (Content)
EMB	Environmental Management Bureau
ERDB	Ecosystems Research and Development Bureau
FIT	Feed In Tariff
GHG	Green House Gas
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
GWP	Global Warming Potential
H_2S	Hydrogene Sulphide
HCF	High Calorific Fraction
HSE	Health, Safety and Environment
ICLEI	International Council for Local Environmental Initiatives
ICLEI SEAS	ICLEI Southeast Asia Secretariat
IEC	Information Education Campaign
LFG	Landfill Gas
LGU	Local Government Units
MBT	Mechanical Biological Treatment
MBR	Membrane Bio-Reactor
MENRO	Municipal Environment and Natural Resources Office
MLSS	Mixed Liquor Suspended Solids
MRF	Materials Recovery Facility

MSW	Municipal Solid Waste
MYT®	Maximum Yield Technology
MZR	Multi Zone Reactor
NIMBY	Not In My Back Yard
NSO	National Statistics Office
OPEX	Operational Expenses
PESWM	Philippine Ecological Solid Waste Management (Act)
PG-ENRO	Provincial Government Environment and Natural Resources Office
pH	potential Hydrogen
PPE	Personal Protection Equipment
PSWMB	Provincial Solid Waste Management Board
PUB	Public Utility Bus
PUJ	Public Utility Jeep
PUV	Public Utility Vehicle
RA	Republic Act
RDF	Refuse Derived Fuel
SLF	Sanitary Land Fill
SW	Solid Waste
SWM	Solid Waste Management
TAP	Toyota Autoparts Philippines, Inc.
UN-ESCAP	United Nations Economic and Social Commission for Asia and the Pacific
UF	Ultra-Filtration
WACS	Waste Analysis and Characterization Study
WtE	Waste to Energy
ZAK	Zweckverband Abfallbehandlung Kahlenberg

1. EXECUTIVE SUMMARY

Towards the end of the last century the Philippines (like many Asian countries with fast growing populations) found themselves facing severe environmental problems like inadequate or non-existing waste management.

As a consequence, the Republic of the Philippines ratified in 2001 the Republic Act No. 9003 (RA 9003) which is also known under the name “Ecological Solid Waste Management Act of 2000”. Later that year, the respective Administrative Order DAO 2001-34 was released. The two documents defined first goals in waste management and a basic political structure for its implementation and were the first steps towards a new approach on waste management in the Philippines.

Associated with this was the implementation of a waste analysis and characterization study (WACS) as well as the development of 10 year’s solid waste management plans (SWM plans) for the towns and municipalities and also for the provinces.

The realisation of these goals required new political structures such as the SWM Boards on municipal and provincial levels and it required training of civil servants at all levels, especially in the Local Government Units (LGUs).

As a result of these newly created structures, the forces of the LGUs are now to be bundled as they merge into clusters. Within these clusters, coordinated waste management concepts are to be pursued and where economically feasible, they must be transposed using centralized facilities.

This report provides information on waste management concepts for the Province of Laguna (Philippines). The approach is taking into account that customized concepts have to be developed for the individual Local Government Units (LUGs) as well as for the existing waste disposal sites. This report also highlights possibilities for cooperation between individual waste disposal sites. This clustering brings about synergy effects and cost savings for the municipalities involved.

The report also provides a brief overview on existing waste processing and recycling structures in Santa Rosa and Binan City as well as a summary on operational aspects on the San Pedro Sanitary Landfill (called “Pilotage”).

The analysis undertaken in this report shows various waste facilities in the Philippines and their potential for improvement. For future new waste disposal techniques, four different solutions have been identified, taking into account the technical and financial possibilities of the respective waste management authorities. All options assume that recyclable substances are already segregated at household level. Those recyclables & reusable substances that are not segregated at the point of origin, should be separated and converted into usable products at the waste treatment plant. This could be for example compost for agricultural use, recyclable materials or substances with an optimal condition for energy recovery in industrial processes.

The basic idea for a waste management strategy in the Laguna Province is that there is *one* general treatment concept that comprises several process stages. These stages can be combined in such a way that each LGU gets the best-suited solution. Thus one concept can be used to cater for the different needs of the individual LGUs.

The proposed process stages that can be part of such a waste treatment concept are:

- Decentralized concept: Locally-built, technically simple, for low waste quantities
- Decentralized concept: Technically more sophisticated, for medium waste quantities
- Centralized concept: Treatment plant for several cities, for larger waste quantities
- Centralized concept: Energetic utilization of high calorific fraction and Refuse Derived Fuel (RDF)

In the following, centralized solutions for the urban areas and decentralized concepts for the rural areas shall be depicted as well as the processes and technologies involved and the CAPEX and OPEX for these processes will be presented.

2. INTRODUCTION AND BASICS

The Urban Nexus approach is aiming for integrated planning and management processes which can contribute substantially to the sustainability of cities and their regions. The United Nations Economic and Social Commission for Asia and the Pacific (UN-ESCAP) and the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH are implementing the project "Integrated resource management in Asian Cities: the urban nexus", financed by the German Federal Ministry for Economic Cooperation and Development (BMZ). The project supports up to twelve selected cities in seven countries (China, India, Indonesia, Mongolia, Philippines, Thailand, Vietnam) by providing technical advice to municipal administrations for the design, the planning and, where possible, the implementation of practical Urban Nexus initiatives.

The target group of this approach is the population of Asian Nexus partner-cities suffering from overexploitation und pollution of resources. In Mongolia the approach concerns Ulan Bator (approx. 1,200,000 residents). In China the approach engages the two cities Rizhao and Weifang (approx. 13,000,000 residents) and in Thailand the two cities Chiang Mai und Korat (together with approx. 300,000 residents). On the Philippines the approach is relevant for the cities Naga City and Santa Rosa (together with more than 500,000 residents), in Indonesia it aims at the population of the cities Pekanbaru and Tanjung Pinang (approx. 1,230,000 residents) and in Vietnam the city and special development zone Da Nang (approx. 770,000 residents) are concerned. With the "extension towards the south" the integration of two Indian cities Nagpur and Rajkot has taken place.

The task includes the Nexus partner cities and their relevant municipal departments (Da Nang / Vietnam, Tanjung Pinang / Indonesia and Santa Rosa / Philippines) in their approach on renaturation or projected shutdown of landfill sites and set-up of an alternative waste disposal infrastructure and waste treatment methods.

Like many Asian countries with fast growing populations, the Philippines found themselves facing severe environmental problems by the end of the 20th century. Many of these problems were a result of inadequate or non-existing waste management.

As a consequence, the Republic of the Philippines ratified in 2001 the Republic Act No. 9003 (RA 9003) which is also known under the name “Ecological Solid Waste Management Act of 2000”. Later that year, the respective Administrative Order DAO 2001-34 was released. In Figure 1 the implementation of RA 9003 in the Philippines is shown.

These were the first steps towards a new approach on waste management in the Philippines. They defined first goals in waste management and a basic political structure for its implementation. Among the goals was the execution of a Waste Analysis and Characterisation Study (WACS) for each community in order to collect data on the amount and characteristics of the waste. Another goal was the development of 10 years solid waste management plans (SWM Plans) for the cities & and municipalities and – subsequently - for the Provinces, all based on the data collected by the WACS.

The realisation of these goals required new political structures such as the SWM Boards on municipal and provincial levels and it required training of civil servants at all levels, especially in the Local Government Units (LGUs).

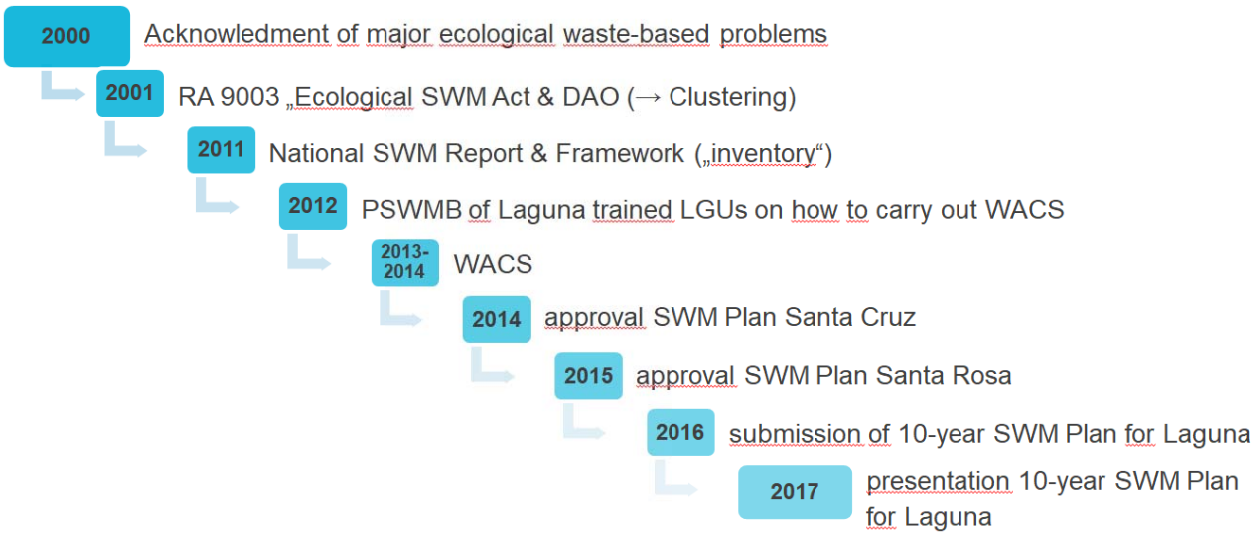


Figure 1: Implementation of RA 9003 in the Philippines (Reference: WEHRLE)

WEHRLE has been involved in the GIZ in the Urban Nexus Project since 2016. WEHRLE's task is to elaborate Feasibility Studies on behalf of the GIZ Urban Nexus Project and to support the partner cities to improve solid waste management. WEHRLE in particular provides ideas and concepts for a future-oriented and sustainable waste management strategy.

This report presents an overview of WEHRLE's suggestions for a waste management strategy for the Province of Laguna, Philippines.

3. PROVINCE OF LAGUNA

Most of the information in the chapters 3.1 to 3.7.4 was directly taken from the Provincial 10-Year SWMP 2015-2024 Province of Laguna.

3.1. LOCATION AND LAND AREA

The Province of Laguna is located 30 kilometres away from Manila. It is the first province south of the Metro Manila area. Laguna is bounded on the North by Laguna de Bay end the province of Rizal; Northeast by the Sierra Madre Mountain Range; East by Quezon Province, South by Batangas and west by Cavite. Laguna lies within the CALABARZON region, one of the country's most progressive and dynamic industrial regions. The CALABARZON Region includes the Provinces of Cavite, Laguna, Batangas, Rizal, Quezon. Laguna's proximity to Metro Manila makes it a strategic area for local and international business.

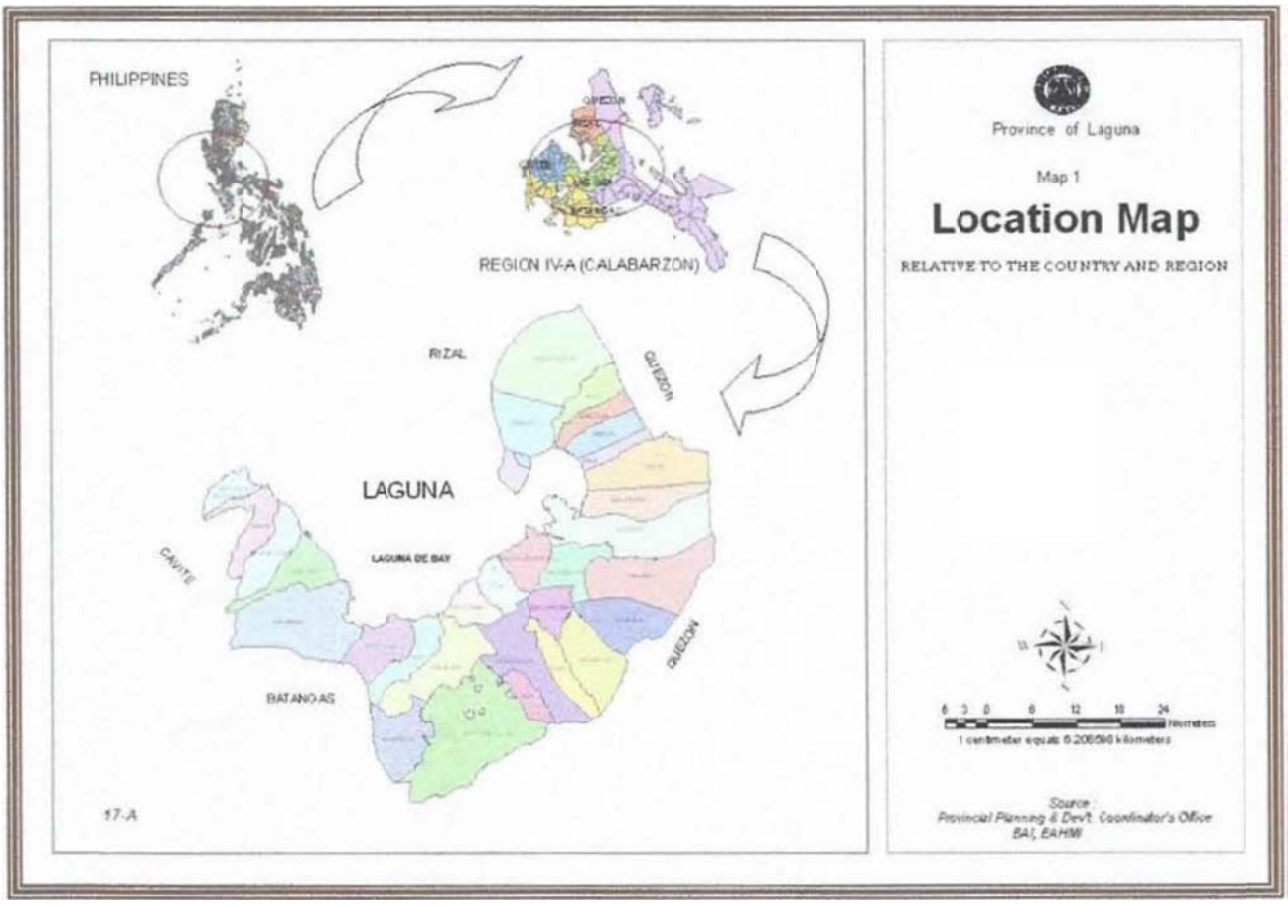


Figure 2: Location Map of the Province of Laguna (Reference: Provincial 10-Year SWMP 2015-2024 Province of Laguna)

Laguna has a total area of 175,973 hectares (or about 1,759.7 sq. km), the second smallest province in Region IV-A (CALABARZON). Its size is approximately 3.75 % percent of the whole Region IV and about 0.58 % percent of the total land area of the country. Its component LGUs comprise of

twenty four (24) municipalities and six (6) cities. The Provincial capital is Santa Cruz. Eighteen (18) LGUs belong to the coastal zone which include: San Pedro City, Binan City, Santa Rosa City, Cabuyao City, Calamba City, Los Banios, Bay, Calauan, Victoria, Pila, Santa Cruz, Lumban, Kalayaan, Pangil, Pakil. Paete, Siniloan and Mabitac. The lakeshore area has a total coastal length of 109.2 km or about 49.64 % percent of the total coastal length of Laguna de Bay. Its lakeshore area has a total lakeshore zone of 580.2 sq. km or 57.37 hectares.

3.2. POPULATION

Based on the National Statistics Office (NSO) census, the Province of Laguna's registered population as of May 1, 2010 is 2,669,847. The fastest growing municipality is Cabuyao while Cavinti has the slowest growth rate. The LGU with the highest population is the City of Calamba with a total population of 389,377. The result of the NSO 2007 census showed that there is an increase at about 25.82 % percent or 507,658 persons over the 2000 census figures. It is estimated that there will be a 3.22 % annual growth rate for the year 2000-2007. Within the CALABARZON Region, Laguna ranks second and ranks fourth as the highly populated nationwide. The NSO projected that for the year 2015 the population of the Province of Laguna will be 3,270,984.The population of Laguna is expected to double in the next 21 years.

3.3. PHYSICAL CHARACTERISTICS

3.3.1. GEOGRAPHY / GEOLOGY

Laguna's terrain consists mainly of narrow plains extending along the eastern, southern and western shores of the famous Laguna de Bay. In fact, more than half, or at least seventeen (17) of its thirty municipalities are either along the Bay shores or a portion of them touching the Bay shores.

3.3.2. CIMATE

The province is relatively dry from November to April and wet during the rest of the year. The other parts, west of Santa Cruz, experience a dry season from November to April, and rainy season during the rest of the year. The eastern and southern most portion do not have distinct seasons, with rainfall more evenly distributed throughout the year.

Rainfall occurs frequently during the months of May to November. Generally, the month of August has the highest precipitation. It is from June to November that the coastal areas most often experience rainfall.

According to available meteorological data for Metro Manila (World Weather Information Service at http://worldweather.wmo.int/en/home.html), the average rainfall during the dry season (November - April) is ~ 44 mm and during the rainy season (May - October) is ~ 304 mm (see Table 1).

The daily maximum temperature ranges from ~ 29 to ~ 33°C (see Table 1). The site is therefore categorized as very humid and hot, potentially enhancing the rate of waste degradation and leachate generation in the landfill.

Table 1: Climatological Information for Metro Manila (Reference: http://worldweather.wmo.int/en/city.html?cityId=92)

Month	Mean Daily Minimum Temperature (°C)	Mean Daily Maximum Temperature (°C)	Mean Total Rainfall (mm)
Jan	23.5	29.5	19.0
Feb	23.8	30.5	7.9
Mar	24.9	32.1	11.1
Apr	26.2	33.5	21.4
May	26.7	33.2	165.2
Jun	26.2	32.2	265.0
Jul	25.8	31.1	419.6
Aug	25.5	30.6	486.1
Sep	25.5	30.9	330.3
Oct	25.5	30.9	270.9
Nov	24.9	30.7	129.3
Dec	23.9	29.7	75.4

Figure 3: Climatological Information for Metro Manila (Reference: http://worldweather.wmo.int/en/city.html?cityId=92)

3.4. CURRENT SOLID WASTE MANAGEMENT CONDITIONS

3.4.1. SOURCE REDUCTION

Waste reduction practices of component LGUs in the Province of Laguna are established. Through the conduct of seminars and meetings MENROs/CENROs encourage communities to practice waste segregation at source, reduce, re-use, recycle (3Rs) and promote backyard composting. However, there is poor compliance on waste segregation in the household level. Open burning and indiscriminate dumping of waste is still in practice. LGUs implement "No Segregation → No Collection Policy" (Reference: Provincial 10-Year SWMP 2015-2024 Province of Laguna).

3.4.2. COLLECTION

Municipalities are implementing segregated collection at source and only five (5) LGUs still practice mixed waste collection. LGUs are implementing the "No Segregation → No Collection Policy" yet compliance is still low. Twenty-six (26) out of thirty (30) LGUs are implementing daily collection of municipal solid wastes within their collection areas. Other LGUs implement waste collection on a per schedule basis in the upland rural areas where houses are distant from one another and are located far from the municipal centralized MRF where daily collection is impractical. This system of collection was made in order to minimize transport cost and increase collection efficiency in the upland barangays. The table below is the LGU current SWM collection activities in the province of Laguna.

Table 2: LGUs Current SWM Collection Activities in the Province of Laguna (Reference: Provincial 10-Year SWMP 2015-2024 Province of Laguna)

City/Municipality	Segregated Collection		Frequency of Collection	No. of Barangays Served
	Yes	No		
Binan City		✓	Daily	24
San Pedro		✓	Daily	20
Sta. Rosa City	✓		Daily	18
Cabuyao		✓	Daily	15
Calamba City		✓	Daily	54
Los Banos	✓		Daily	12
Bay	✓		Daily	15
Alaminos	✓		Daily	15
Calauan	✓		Daily	16
Liliw	✓		Daily	22
Nagcarlan	✓		Schedule basis	19
Rizal	✓		Daily	11
San Pablo City	✓		Daily	80
Victoria	✓		Daily	9
Cavinti	✓		Daily	
Famy		✓	Schedule Basis	10
Kalayaan	✓		Daily	3
Luisiana	✓		Daily	18
Lumban	✓		Daily	16
Mabitac	✓		Daily	14
Magdalena			Schedule Basis	20
Majayjay	✓		Daily	24
Paete	✓		Daily	9
Pagsanjan	✓		Daily	11
Pakil	✓		Daily	11
Pangil	✓		Daily	7
Pila	✓		Schedule basis	9
Sta. Cruz	✓		Daily	26
Sta. Maria	✓		Daily	8
Siniloan	✓		Daily	15

3.4.3. TRANSFER

LGUs within the 2nd, 3rd, and 4th districts have centralized Materials Recovery Facility (MRF) owned and managed by each municipality. The MRF serves as a transfer station for residual waste that is transported and disposed of by LGUs. It also provides for the storage of recyclable wastes, composting of biodegradable wastes and storage area for the residual wastes. LGUs identify temporary transfer stations in the purok (district), sitios (enclave) and barangays as pick-up points for the efficient collection and transport of wastes. The waste is then to be transferred to the centralized MRF of each LGU. Most LGUs in the 1st and 2nd district have contracts with private sanitary landfill operators. Solid waste is brought from the source to designated pick-up points in the barangays and sent directly to the sanitary landfills by private contractors.

3.4.4. PROCESS FACILITIES

Table 3 indicates the number of MRFs and composting facilities in the LGUs. To date twenty (22) LGUs in the municipal level of Laguna Province have established their own centralized Materials Recovery Facility. This serves as the processing of biodegradables into compost, storage of recyclable materials and processing of agricultural wastes into charcoal briquettes, plastic residuals storage and shredding. Out of 674 barangays in the province only 118 barangays have established their own barangay MRF.

The stored recyclable materials in the MRF are sold in bulk to junkshop operators. Sales from the recyclable materials are often used as salaries and incentives for the labourers in the MRF. Biodegradable wastes collected are processed into compost using bioreactors, windrows composters, rotating drum composters and also through vermi-composting. Other residual plastic wastes are used in making hollow blocks, bricks and tiles.

Table 3: Summary of LGUs MRF and Composting Facility As of June, 2015 (Reference: Provincial 10-Year SWMP 2015-2024 Province of Laguna)

City/ Municipality	Municipal MRF		Number of Barangay			
	Yes	No	With MRF	Without MRF	Practice Composting	
					Yes	No
Binan City		✓	2	22	✓	
San Pedro		✓	1	19	✓	
Sta. Rosa City	✓		2	16	✓	
Cabuyao		✓	1	17		✓
Calamba City		✓	3	51		✓
Los Banos	✓		0	14	✓	
Bay	✓		15	0		✓
Alaminos	✓		7	8	✓	
Calauan	✓		2	15	✓	
Liliw	✓		1	32	✓	
Nagcarlan	✓		1	51	✓	
Rizal	✓		0	11	✓	
San Pablo City	✓		0	80	✓	
Victoria	✓		0	9	✓	
Cavinti	✓		18	1	✓	
Famy		✓	0	20		✓
Kalayaan	✓		3	0	✓	
Luisiana	✓		14	9	✓	
Lumban		✓	0	16		✓
Mabitac	✓		14	1	✓	
Magdalena		✓	0	24		✓
Majayjay		✓	0	40		✓
Paete	✓		0	9	✓	
Pagsanjan	✓		1	15	✓	
Pakil	✓		7	6	✓	
Pangil	✓		0	8	✓	
Pila	✓		4	13	✓	
Sta. Cruz	✓		14	12	✓	
Sta. Maria	✓		0	25	✓	
Siniloan	✓		8	12	✓	
TOTAL	**22**	**8**	**118**	**556**	**23**	**7**

3.4.5. FINAL DISPOSAL

Presented in Table 4 is the current type of disposal facilities used by the LGUs in the Province of Laguna. Thirteen (13) LGUs are in contract with private SLF operators which provide the hauling and disposal of their solid wastes. Four (4) LGUs have established their own SLF as their final disposal facility. Nonetheless there are nine (9) LGUs operating controlled dumps while four (4) LGUs

still use their open dumpsites. Province wide, informal settlers and scavengers are strictly not allowed to dwell in the disposal facilities. Scavengers are organized to work as waste segregators in the disposal facility through an ID system. They are allowed to collect and sell recyclable materials provided that they shall perform their duties and responsibilities as authorized wastes segregators in the area. This target created a harmonious relationship between the LGUs, waste segregators and informal settlers.

Table 4: LGUs Disposal facilities in the Province of Laguna As of June, 2015 (Reference: Provincial 10-Year SWMP 2015-2024 Province of Laguna)

*OD-Open Dump			*CD-Controlled Dump		*SLF-Sanitary Landfill
Municipality/ City	OD	CD	LGU SLF	Contract with Private SLF	Final Disposal Site
City of San Pedro				/	Pilotage Trading and Construction
City of Biñan				/	Suri Waste Management and Disposal Services
City of Santa Rosa				/	Pilotage Trading and Construction
City of Cabuyao				/	Suri Waste Management and Disposal Services
City of Calamba				/	Suri Waste Management and Disposal Services
Los Banos				/	Pilotage Trading and Construction
Bay			/		Suri Waste Management and Disposal Services
City of San Pablo			/		City SLF
Alaminos				/	Suri Waste Management and Disposal Services
Nagcarlan				/	Suri Waste Management and Disposal Services
Rizal				/	Suri Waste Management and Disposal Services
Liliw		/			
Victoria	/				
Calauan				/	Suri Waste Management and Disposal Services
Majayjay		/			
Magdalena		/			
Pagsanjan				/	Suri Waste Management and Disposal Services
Santa Cruz				/	Suri Waste Management and Disposal Services
Pila				/	Suri Waste Management and Disposal Services
Cavinti		/			
Lumban	/				
Kalayaan			/		Municipal SLF
Paete			/		Municipal SLF
Pakil		/			
Pangil	/				
Siniloan		/			
Mabitac		/			
Famy	/				
Santa Maria		/			
Luisiana		/			
TOTAL	**4**	**9**	**4**	**13**	

3.4.6. COSTS AND REVENUES

As presented in Table 5 the consolidated budget/expenditures of LGUs on Solid Waste Management for the whole province is approximately PHP 610,500,000 per annum. Component Cities* have the highest allocation for SWM wherein approximately 50 % of their total budget are used as payment for services to private contractors for the hauling and disposal of generated waste in their respective areas. There are about PHP 137,100,000 estimated total revenues per annum of LGUs from SWM programs. Revenues collected by LGUs come mainly from the collection of environmental fees, revenues from violation fines and penalties and collection from environmental clearances. Nonetheless, the revenues collected are insufficient to compensate the SWM expenses of the LGUs.

* Cities which are administratively and legally not subject to a province, and thus do not share their tax revenues with any province.

Table 5: Consolidated Budget of LGUs on SWM Programs (Reference: Provincial 10-Year SWMP 2015-2024 Province of Laguna)

City/ Municipality	Annual Budget (Php)	Revenues (Php)	Remarks
Binan City	116,730,772.00	5,072,033.00	2015
San Pedro	69 M	8,900,000.00	2015
Sta. Rosa City	299,300,000	8,000,000.00	2014
Cabuyao	104,150,503.66	556,836.88	Annual Budget = 2014 Revenues = 2015
Calamba City	141,627,949	96,880,814.00	Revenues = 2016
Los Banos	18,455,932	10,868,944.00	2013budget, revenues based on the sale of recyclables on annual target of diversion
Bay	2,000,000.00		2014 payment for contracting services
Alaminos	2,326,756.60		2014
Calauan	5,573,000.00	22,200.0	2015 budget 2013 revenue garbage fee/business permit
Liliw	3,346,200.04	212,650.00	2014
Nagcarlan	5,100,000.00	191,925.00	2015 budget 2012 revenue from garbage fee and business applications
Rizal	3,588,575.39		2015 budget
San Pablo City	30,492,191.00	4,243,521.58	2014 budget Revenues collected for garbage fees and business permits
Victoria	2,750,000.00		2014 budget

Cavinti	1,691,220.00		2015budget
Famy	1,137,900.00	50,380.00	2014 budget 2015 revenue garbage fee
Kalayaan	3,895,999.20		2011
Luisiana	1,918,000.00		2014
Lumban	2,758,000.00		2015
Mabitac	1,498,002.04		2014
Magdalena	205,000.00		2015
Majayjay	3,150,000.00		2015
Paete	11,998,933.00	40,000.00	2015 construction of SLF facilities and equipments
Pagsanjan	8,699,701.09		2015
Pakil	1,500,000.00		2014
Pangil	2,353,340.48		2014
Pila	2,213,765.00		2014
Sta. Cruz	27,900,000.00	1,745,000.00	2015
Sta. Maria	2,950,000.00		2015
Siniloan	1,000,000.00	312,240.00	2014 budget 2014 revenue garbage fee
Province of Laguna	504,000.00		2015 budget hauling and maintenance of capitol grounds
Grand Total	**610,445,740.41**	**137,096,544.46**	

3.5. WASTE CHARACTERISTICS

3.5.1. QUANTITY AND COMPOSITION OF WASTE DISPOSED (FROM WACS)

The following Table 6 shows the Waste Analysis and Characterization Study (WACS) for selected cities - focussing biodegradable and recyclable components.

Although the figures in Table 6 give an indication of the ratio of the biodegradable fraction, the information on the water content in the individual fractions is missing.

Table 6: Summary Showing the Quantity and Composition of Waste Disposed per day Based on WACS in the Province of Laguna, CY-2015 (Reference: Provincial 10-Year SWMP 2015-2024 Province of Laguna)

Summary of waste from different WACS for a common recycling and treatment plant; CY 2015

Districts	Major Sources	PCG* kgs/person/ day	Total Waste Generation		Waste Composition (kgs/day)					
			Kgs./day	Percentage	Biodegradable	Recyclable	Residual with Sub Total	Outright for Disposal	Total Residual	Special Waste
I	City of San Pedro	0,485	164.510,35	16,29%	74.725,97	50.534,58	16.453,90	18.951,75	35.405,64	3.844,15
I	City of Biñan	0,364	120.237,06	11,90%	61.722,56	33.472,58	13.334,30	10.643,32	23.977,64	1.064,27
I	City of Santa Rosa	0,699	246.570,06	24,41%	153.553,90	42.626,62	24.247,10	23.996,21	48.243,32	2.146,22
II	City of Cabuyao	0,469	177.755,00	17,60%	82.037,90	37.951,93	15.648,18	37.442,47	53.090,65	4.674,52
II	City of Calamba	0,409	187.564,19	18,57%	100.116,41	45.412,01	21.548,27	19.147,16	40.695,43	1.340,34
III	City of San Pablo	0,425	113.468,12	11,23%	51.182,54	37.385,16	9.349,36	14.480,66	23.830,02	1.067,14
	GRAND TOTAL		1.010.104,79	100%	523.339,29	247.382,89	100.581,14	124.661,57	225.242,71	14.134,64
			100,00		51,81	24,49			22,30	1,40

Reference: Provincial 10-Year Solid Waste Managent Pland - Province of Laguna 2015

The following Table 7 shows the Waste Analysis and Characterization Study (WACS) for several sampling points at San Pedro Landfill - focussing the general waste composition.

As well as the above table Table 7 it does not provide any information on the water content in the waste samples.

Table 7: Waste Analysis And Characterisation Study of Municipal Solid Waste (MSW) generated by Municipality of San Pedro Laguna Sanitary Landfill Facility November 4-5 2015 (Reference: dnc Environmental Resarch Services)

WASTE ANALYSIS AND CHARACTERIZATION STUDY OF MUNICIPAL SOLID WASTE (MSW)
GENERATED BY MUNICIPALITY OF SAN PEDRO LAGUNA SANITARY LANDFILL FACILITY
November 4-5 2015

Project Title : Waste Analysis and Characterization Study (WACS)
Date of Analysis : November 5, 2015
Location : San Pedro Laguna Sanitary Landfill, Barangay San Antonio, Municipality of Laguna
Source : Residential, Commercial, Industrial, Agricultural, etc.
Duration : Eight (8) hours (8:00am – 5:00pm) with one-hour rest period
Weather : Cloudy
Sorters : Thirty (30) persons

SAMPLING POINTS	CLOTHES/ SHOES	BOTTLES	TIRE/ RUBBER	DIAPERS	BIO WASTE	WOODS	CAN	PAPERS/ CARTON	STYRO FOAM	TAR PAULIN	SACKS	PLASTIC	CELLOPHANES	
SP 1	4.5	-	-	1.3	18	-	-	8	-	-	-	2.5	4.4	
SP 2	-	-	5.5	-	13	2	-	5	-	-	-	2	5	
SP 3	-	-	-	-	13	1	-	4.5	1	-	-	-	3.2	
SP 4	8	5	-	10	14	1	1.5	5	-	-	-	-	3	
SP 5	3.2	-	-	-	11.5	-	-	1.5	-	-	-	-	4.5	
SP 6	-	-	-	4	7.2	-	-	4	.2	-	-	-	2	
SP 7	1.3	1	-	-	14.2	-	-	6	-	-	-	-	3.5	
SP 8	-	-	-	-	7	2	-	2	-	-	2.5	-	2.3	
SP 9	-	-	-	12	20	-	-	5	-	-	-	-	4.2	
SP 10	1.5	-	-	-	23	-	-	8	-	-	-	-	5	
TOTAL WEIGHT (kgs)	18.5	6	5.5	27.3	140.9	6	1.5	49	1.2	0	2.5	4.5	37.1	300 kgs.
PERCENTAGE (%)	6.17%	2%	1.83%	9.1%	47%	2%	0.5%	16.33%	0.4%	-	0.83%	1.5%	12.3%	100 %

3.5.2. QUANTITY AND COMPOSITION OF WASTE (FOR DESIGN ESTIMATIONS)

Due to incomplete data, the different waste fractions from the Waste Analysis and Characterization Study (WACS) was supplemented with assumed water content in order to obtain design values for the technical treatment process (see Table 8 below).

Table 8: Characterization and water content for design purposes (Reference: WEHRLE)

MYT PROJECT **"Example Laguna"** **Design Values and design estimations**

Municipal Solid waste 1000 t/d 365.000,00 t/a

								Mechanical separation RDF1				
					DM							
		Waste amount	Water amount in each fraction		Dry matter in the waste			Sieve Under-cut (100 mm) in	Sieve Under-cut in	Sieve Over-flow in	DM in Sieve Overfow	
	%	t/year	%	t/year	%	t/year	t/d	%	t/d	t/d	t/d	t/a
Organic waste	47,00	171.550	80,0	137.240	20	34.310	470	90	423	47	9,4	3.431
wood	2,06	7.519	25,0	1880	75	5.639	21	35	7	13	10,0	3.666
Paper & Cardboard	16,30	59.495	25,0	14.874	75	44.621	163	35	57	106	79,5	29.004
Textil	6,17	22.521	25,0	5630	75	16.890	62	35	22	40	30,1	10.979
Leather and Rubber	1,83	6.680	25,0	1670	75	5.010	18	35	6	12	8,9	3.256
Plastic Mix and Bags	24,10	87.965	25,0	21.991	75	65.974	241	35	84	157	117,5	42.883
Metal	0,50	1.825	2,0	37	98	1.789	5	35	2	3	3,2	1.163
Glas/Porcelan/stones/Coal/Cinder/soil/Sand	2,00	7.300	2,0	146	98	7.154	20	35	7	13	12,7	4.650
Others/Hazardous	0,10	365	2,0	7	98	358	1	35	0	1	0,6	233
	100,06	365.219	50,24	183.475		181.744	1.001		609	392	272	99.263

3.6. LEGAL AND INSTITUTIONAL FRAMEWORK

3.6.1. LOCAL LAWS AND REGULATION

In the Provincial 10-Year SWMP 2015-2024 Province of Laguna ordinances related to solid waste management of LGUs are presented. Ordinances common to LGUs address the regulation on use of plastic bags and styrofoam, anti-littering, proper segregation, collection and disposal of wastes, mandatory placement of garbage receptacle on PUV, PUJ and PUB. These local policies shall be reviewed, updated and amended to conform with the RA 9003 (as stated in the Provincial 10-Year SWMP 2015-2024 Province of Laguna).

3.6.2. ROLES OF THE PROVINCIAL SOLID WASTE MANAGEMENT BOARD (PSWMB)

The Provincial Solid Waste Management Board (PSWMB), which is chaired by the Provincial Governor, as stated in Rule VI, Section 2 of the Implementing Rules and Regulations of RA 9003 shall have the following functions, roles and responsibilities:

a) Develop a provincial solid waste management plan from the submitted solid waste management plans of the respective city and municipal solid waste management boards of LGUs. It shall review and integrate the submitted plans of oll its component cities and municipalities and ensure that various plans complement each other, and have the requisite components.
   The provincial plan shall reflect the general program of action and initiatives of the provincial government in implementing a solid waste management program that would support the various initiatives of its component cities and municipalities.
b) Provide necessary logistical and operational support to its component cities and municipalities in consonance with subsection (f) of Section 17 of the Local Government Code.
c) Recommends measures and safeguards against pollution and for the preservation of the natural ecosystem.
d) Recommend measures to generate resources, funding and implementation of projects and activities as specified in the duly approved solid waste management plans.
e) Identify areas within its jurisdiction, which have common solid waste management problems and are appropriate units for planning local solid waste management services in accordance with Section 41 of the Act.
f) Coordinate the efforts of the component cities and municipalities in the implementation of the Provincial Solid Waste Management Plan.
g) Develop an appropriate incentive scheme as an integral component of the Provincial Solid Waste Management Plan.
h) Convene joint meetings of the provincial, city, and municipal solid waste management boards at least every quarter for purposes of integrating, synchronizing, monitoring and evaluating the development and implementation of its provincial solid waste management plan.

i) Represent any of its components city or municipality in coordinating its resource and operational requirements with agencies of the national government.
j) Oversee the implementation of the Provincial Solid Waste Management Plan.
k) Review every two (2) years or as the need arises, the Provincial Solid Waste Management Plan for purposes of ensuring its sustainability, viability, effectiveness and relevance in relation to local and international development in the field of solid waste management.
l) Allow for the clustering of LGUs for the solution of common solid waste management problems.

More details on the historical background and the approaches of the PSWMB are provided in the Provincial 10-Year SWMP 2015-2024 Province of Laguna.

3.6.3. CITY/MUNICIPAL SOLID WASTE MANAGEMENT BOARD (C/MSWMB)

Component LGUs have already organized their respective Solid Waste Management Boards. However, most Local SWM Boards are inactive and few convene on a regular basis.

Details on the C/MSWMB formed and a schedule of meetings per LGU are provided in the Provincial 10-Year SWMP 2015-2024 Province of Laguna.

3.7. PLAN / STRATEGY

3.7.1. VISION

The Provincial Government of Laguna aims to have an integrated, collaborative, pro-active and sustainable solid waste management program that will benefit both the people and the environment. Programs and activities shall be in harmony with nature that warrants for a clean, safe, liveable and ecologically sound environment for the present and succeeding generation (as stated in the Provincial 10-Year SWMP 2015-2024 Province of Laguna).

Goals:

1. To integrate the various solid waste management plans, programs and strategies of the 24 Municipalities and 6 cities in the Province of Laguna.
2. To develop strategies and recommend local policies that will ensure effective and efficient collection, treatment, storage, transport and disposal of solid waste in the Municipalities and Cities.
3. To ensure protection of the environment, public health and safety through proper treatment and disposal of wastes.
4. To increase compliance of LGUs on waste segregation and waste diversion through community participation.

5. To enhance the capabilities, knowledge and expertise of LGUs on SWM technologies and practices.
6. To encourage and support LGUs in the implementation of their respective solid waste management projects, provide incentive mechanisms and develop livelihood programs as the offshoot of the SWM program.
7. To promote and encourage backyard composting and use of compost as soil enhancer/conditioner.
8. To establish strong partnership with private entities on recycling and waste diversion mechanism such as co-processing of residual wastes and the like.
9. To serve as a model province on ecological solid waste management practices and programs.

3.7.2. TARGETS

Details on the “Diversion and Disposal Targets and Distribution of Diversion Target of the province, CY 2015-2024” are provided in the Provincial 10-Year SWMP 2015-2024 Province of Laguna.

3.7.3. APPROACH

Plan Strategies in order to fulfil the targets (see 3.7.2) of the Provincial 10-Year SWMP 2015-2024 Province of Laguna are defined as follows:

1. Source Reduction
   → LGUs major source reduction programs, specific waste reduction approaches for each specific waste generator/sector, type of waste to be diverted and gaps to be addressed by the Province.
2. Collection
   → Municipalities and Cities shall be responsible for the collection of residual wastes while the Barangays shall have the responsibility of establishing and operating their own Materials Recovery Facility. The Barangays shall be primarily responsible for the collection of household segregated wastes which shall be processed and stored in the MRF
3. Segregation, Recycling and Composting
   → Segregation plays a vital step in the management of solid wastes yet serious collective cooperation and participation of all sectors most specifically the households is aimed by the province to increase compliance on segregation.
   → Recycling activities are already practiced in the province yet a monitoring system on level of compliance shall be made. All Barangays shall be enjoined for the establishment and operation of Materials Recovery Facilities.
   → Based on the result of the WACS for the Province of Laguna, biodegradable wastes comprise approximately 58.16 % of the total wastes generated. Through the practice of composting the large volume of biodegradable waste can be diverted out of the waste stream. LGUs shall be enjoined to create local ordinances on the practice of backyard

composting and other means of composting practices for its implementation all throughout the province.

4. Transfer
   Laguna province will identify clustered collection points and aims to establish two (2) Centralized Clustered District MRF's (CCDMRF). These facilities will serve as storage and transfer station of wastes such as: a) residual plastics for co-processing to cement factories and b) agricultural wastes/rice stalks/wood trimmings/ water lilies as raw materials for composting and livelihood programs like charcoal briquetting and handicrafts making.
5. Alternative Technologies for Residual Wastes
   With the proposed establishment of two (2) Centralized Clustered District MRF's (CCDMRF) the province propose to acquire multi-purpose shredding machines, smelting machines, bailing machines, rapid composting machines for the CCDMRF. The CCDMRF shall serve as transfer station, storage facility and processing of plastic residuals that will cater services from the clustered LGUs. Other alternative technologies such as processing of plastic sando bags and styrofoam into tiles, bricks, boards and other functional products; thermal processing of plastics into chairs and tables; processing of plastics into paint and plastics as fillers into asphalt cements shall be considered. Cement processing plants shall also be tapped to facilitate collection of other plastic residuals in the CCDMRF. The province shall propose a scheme on "waste to cement program" wherein the province shall provide cement plants plastic residual wastes in exchange for cement.
6. Disposal
   By year 2017 it is estimated that 60 % of the activities in the Safe Closure and Rehabilitation Plan of LGUs open and controlled disposal sites have already been implemented. For the 10 year planning period, LGUs plan to avail contract of service with private sanitary landfill operators in hauling and disposal of residual wastes. Nineteen (19) out of thirty (30) LGUs or approximately 63 % opt to operate a centralized MRF rather than to establish and operate a SLF. The implementation of the SAFE CLOSRE AND REHABILITATION of open and controlled disposal facilities by the LGUs shall be closely monitored by the province through the Provincial Government Environment and Natural Resources Office (PG-ENRO).
   The province shall allow LGUs to borrow its heavy equipments for the rehabilitation and safe closure of disposal facilities. The Province envisions in the future to establish two (2) Clustered Waste to Energy Plants with Sanitary Landfill facilities that will assist LGUs in the management and treatment and disposal of their wastes. Clustering shall be spearheaded by the Province. The clustering process shall be executed through the following steps (see 3.7.4).

3.7.4. CLUSTERING OF LGUS

There are four (4) congressional Districts in the Province of Laguna. The province aims to group them into two (2) clusters. **Cluster I** shall be composed of LGUs within the 1st and 2nd District: City of San Pedro, City of Binan, City of Sta. Rosa, City of Cabuyao, City of Calamba, Municipalities of Los banos and Bay, while **Cluster II** shall be composed of LGUs within the 3rd and 4th District: Mu-

nicipalities of Calauan, Alaminos, Liliw, Nagcarlan, Rizal, Victoria, Pila, Sta. Cruz, Pagsanjan, Lumban Kalayaan, Paete, Pakil, Pangil, Famy, Siniloan, Mabitac, Sta. Maria, Cavinti, Magdalena, Majayjay, Luisiana and City of San Pablo.

4. SITE VISITS

4.1. SANTA ROSA WASTE PROCESSING DEMONSTRATION SITE

In the City of Santa Rosa (Laguna Province; District 1), a demonstration site is already processing different waste streams to products.

4.1.1. COCONUT COAL BRIQUETTES

To address unwanted organic wastes, the Charcoal Briquetting Livelihood Program was launched in 2010. It aims to lessen the dependence on fuelwood and provide a cheaper and an environment-friendly alternative for the use of liquefied petroleum gas (LPG). It seeks to address the uncontrollable occurrence of water lilies in the coastal barangays of Aplaya, Caingin and Sinalhan. It intends to provide alternative livelihood opportunities for the lakeshore communities.

Figure 4: Charcoal Briquetting Livelihood Program (Reference: CESWM Plan 2016-2025 City of Santa Rosa)

The Toyota Autoparts Philippines, Inc. (TAP) has donated briquetting facilities such as briquettor, carbonizer, grinder, mixer and drier to support the program while a thoroughly training was provided by the Ecosystems Research and Development Bureau (DENR-ERDB). During the carbonizing process, the carbon dioxide that is being produced is collected and condensed as a liquid smoke which can be used for foliar fertilizer.

(Reference: CESWM Plan 2016-2025 City of Santa Rosa)

Coconut shells are dried under the open sky. The pre-dried shells are then charred in oil barrels to obtain a coal-like material, which is milled to dark powder. This fine powder is pressed in cylindrical molds to produce coconut coal briquettes. These briquettes are sold on the local market for cooking purposes.

Figure 5: Coconut shells stored and dried under the open sky (Photo: WEHRLE)

Figure 6: (left) Oil barrels for producing a coal-like material from the dried coconut shells (Photo: WEHRLE)

Figure 7 (right): Milling drums for preparing the coconut coal powder (Photo: WEHRLE)

Figure 8 (left): Coconut coal powder after the milling (Photo: WEHRLE)

Figure 9 (right): Coconut coal briquettes as final product (Photo: WEHRLE)

4.1.2. PET BOTTLE RECYCLING

The same site offers a recycling example how PET bottles, car tires and other materials can be “transformed” to create a showcase for recycling possibilities.

Figure 10: Example for recycling of PET bottles (Photo: WEHRLE)

4.2. BINAN CITY

In the City of Binan (Laguna Procince; District 1) a Material Recovery Facility (MRF) is existing.

In the meeting with the City of Binan officials the following information on existing infrastructure was provided:

- Population 330,000
- Waste generation 0.36 kg/person*day → ~120,000 kg/d MSW (incl. industrial waste)
- Tipping Fee 4,000 – 5,000 PHP/truck (6 wheeler truck)
- From March 2017 on source segregation will be carried out bindingly
- Real collection rate estimated at 50 %
- Waste composition ~51 % biodegradable
- No existing landfill – next landfill is in Calambra, operated by a private company
- One compost facility is in construction phase
- One site for “other waste” waste is existing
- One Material Recovery Facility (MRF) in City of Binan is existing:
  MRF site 5000 m²; 70 tons/day throughput (@ 8-10hours/day operational time); 5-6 years old; 20 Mio PHP were invested in the existing plant in order to upgrade the plant (e.g. new shredder)
- Other available Material Recovery Facilities (MRFs):
  (MRF Langkiwa – in construction phase; MRF Timbao – in operation)
- Land is the problem (for setting-up waste treatment infrastructure)
- No utilisation processes for RDF in place.

Figure 11: (left) Material Recovery Facility (MRF) in City of Binan (Reference: ICLEI)

Figure 12: (right) Material Recovery Facility (MRF) in City of Binan (Reference: ICLEI)

4.3. SAN PEDRO LANDFILL

4.3.1. SITE DATA / OPERATIONAL DATA

In the Municipality of San Pedro the Laguna Sanitary Landfill Facility exists (as stated in the Provincial 10-Year SWMP 2015-2024 Province of Laguna). The San Pedro Sanitary Landfill has been receiving waste since 2003 from some of the Municipalities of Laguna. The landfill consists of Cell 1-5 with an entire area of 18 hectares.

San Pedro Sanitary Landfill is owned and operated by the private company PILOTAGE TRADING AND CONSTRUCTION.

On the San Pedro Landfill site a 4 MW Methane and Power Generation Project was executed between 2007 and 2011 (see Figure 13). According the provided project information 84 landfill gas collecting wells were installed throughout cell 1-4. However, during the visit in 2017, there was no landfill gas well on the landfill visible.

The private company BACAVALLEY ENERGY has been operating this power generation project since 2011. During the site visits in 2017 / 2018 the power generation plant was not in operation for some reasons.

Installed Capacity	4,212 MW (4MW)			
Engine Specs	4 Jenbacher Gas Engines (J320) each with a design capacity of 1053 kW (1MW), contained in 20ft containers			
Engine Efficiency	40.32%			
Fuel Gas LHV		**100% (Full load)**	**75% (Partial load)**	**50% (Half load)**
Gas Volume	Nm^3	679	528	376
Electrical output	kW	1053	789	523

Figure 13: Project data Pilotage San Pedro Landfill (Reference: BACAVALLEY ENERGY)

In the meeting with the officials from PILOTAGE TRADING AND CONSTRUCTION the following information on existing infrastructure was provided:

- Company owns 150 trucks for waste collection
- In total 200-300 trucks/day (40 trucks/day from Santa Rosa) of collected waste are brought to the landfill site
- Each truck takes 24m³; Waste density 350 kg/m³ (NOTE: 200 trucks/day * 24 m³/truck * 350 kg/m³ = 1,680 tons/day! – this daily waste amount is far more than the official figures in Table 6 chapter 3.5.1 indicate
- Total staff 300 (truck drivers / reapers / administration)
- 200-300 families are living nearby the landfill and are involved in the landfill operation (one worker / scavenger per family)
- The site administration provides food and medicine for the workers / scavengers
- Landfill operation in 2 shifts (day / night)
- Waste disposal in layers of 3.5 - 4 m → compacting with bulldozers to a thickness of 2.5 m; the top of each layer is covered with ground / soil
- Odour elimination with spray (PLANTEX Green All in One)

During the following landfill site visit with the officials the following information was provided:

- Waste segregation is done by scavengers
- Leachate collection measures (e.g. pipework, ponds, pumps) are in place
- Since the power generation plant is out of service landfill gas is released to atmosphere (NOTE: Methane = greenhouse gas (GHG); ↑ global warming potential (GWP)
- Odour elimination: 2 gallons of biocide in a solution of 3,200 litres/day; in the dry season no smell (Note: The operator suspects that there will be no methane emissions during the dry season)
- Fresh landfill leachate could not be noticed during the site visit (leachate figures were not provided)
- Tipping fee: 285,701 PHP/ton (~5,5 USD/ton).

4.3.1.1. SITE LOCATION

The San Pedro Sanitary Landfill is connected via Narra Road, located in San Antonio, San Pedro City, 4023 Laguna, Philippines. The distance to the surrounding settlements is only a few hundred meters (see Figure 14: Satellite view of San Pedro Sanitary Landfill (Reference: Google Maps)).

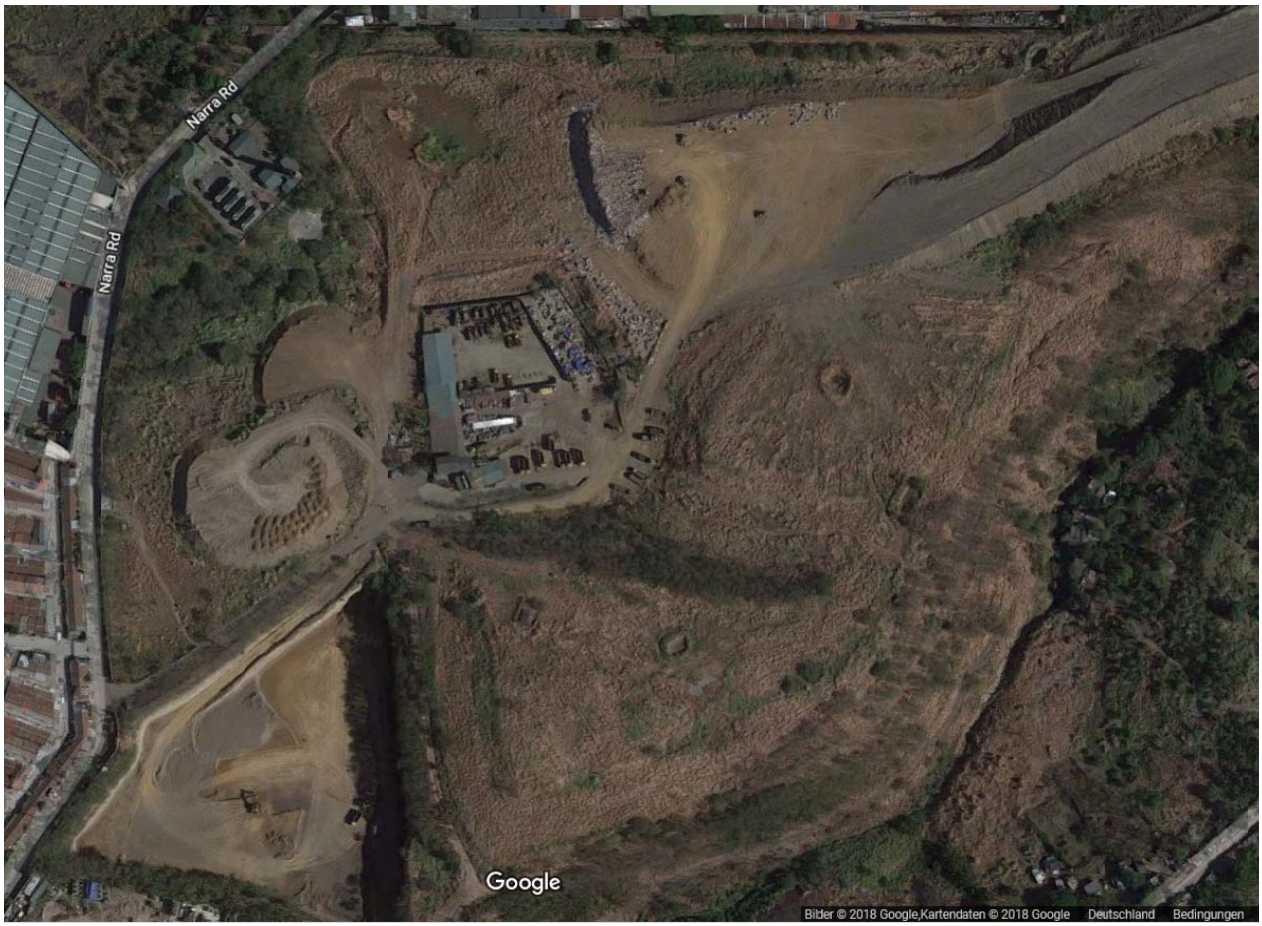


Figure 14: Satellite view of San Pedro Sanitary Landfill (Reference: Google Maps)

4.3.2. LANDFILL OPERATION

The following photos are documenting the waste segregation and disposal as well as operational aspects at San Pedro Sanitary Landfill.

During the site visit in 2017 different issues that may collide with general Health, Safety and Environment (HSE) rules became obvious (see following photos).

Figure 15: Waste truck delivering MSW to the landfill site (Photo: WEHRLE)

Figure 16: Scavengers segregating the waste while waste truck is unloaded (Photo: WEHRLE)

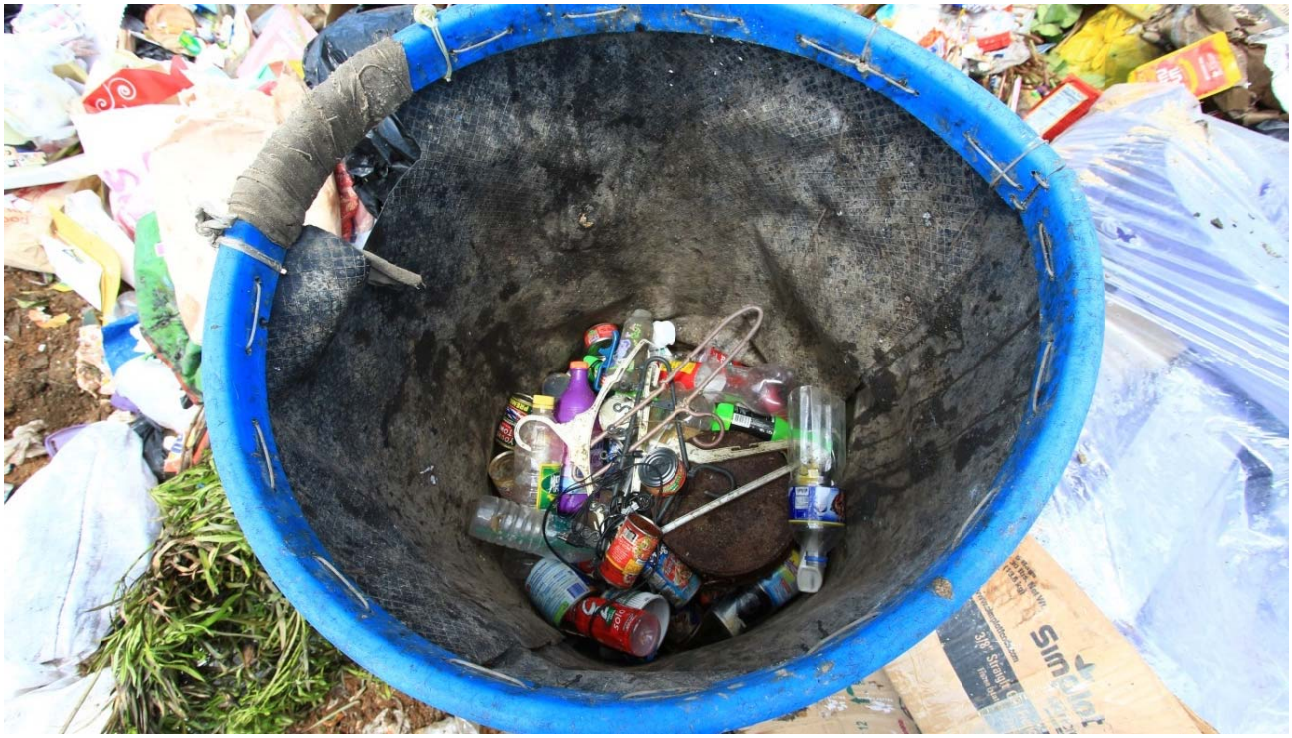


Figure 17: Segregated metal and plastic (Photo: WEHRLE)

Figure 18: Segregated paper (Photo: WEHRLE)

Figure 19: Segregated plastic (Photo: WEHRLE)

Figure 20: Stored recyclables and on site MRF (Photo: WEHRLE)

Figure 21: Caterpillar for waste compacting (Photo: WEHRLE)

Figure 22: Truck with ground for covering the dump site (Photo: WEHRLE)

Figure 23: Site employee preparing the diluted liquid for odour elimination (Photo: WEHRLE)

Figure 24: On site odour elimination (Photo: WEHRLE)

Figure 25: Landfill leachate collecting pond (Photo: WEHRLE)

Figure 26: Shed with leachate pumps (Photo: WEHRLE)

Figure 27: Leaking leachate from the already filled cells of San Pedro landfill (Photo: WEHRLE)

4.3.3. LANDFILL HEALTH, SAFETY AND ENVIRONMENT

During the site visit different issues that may collide with general Health, Safety and Environment (HSE) rules were observed. The most obvious points are highlighted below:

- Danger of falling / drowning (e.g. dumping areas with steep slopes, unfenced leachate ponds)
- There is a danger of being run over due to scavenging behind and around moving vehicles / machines (e.g. waste trucks, bulldozers)
- Poor / inadequate personal protection equipment (PPE) for personnel can cause severe healthiness problems
- Uncontrolled leakage of leachate due to inadequate capturing measures
- Methane (CH_4) is released freely to the atmosphere (Note: greenhouse gas potential of CH_4 is ~20 times higher than CO_2)
- Hydrogen Sulphide (H_2S) is released into the atmosphere (note: H_2S is a highly toxic gas that spreads in low concentrations the typical smell of rotten eggs. At gas concentrations as low as 0.5 ppb H_2S can be perceived by the human nose. At higher concentrations >100 ppm an anaesthesia of the odour receptors occurs. H_2S at concentrations >100 ppm is poisonous after less than one hour of exposure.

Due to the importance and the complexity of this topic it was not possible to address all HSE issues during the site visit because this is the field of qualified and certified HSE experts. The experience with waste and landfill sites does not replace the expertise of a qualified HSE expert. We therefore strongly recommend PILOTAGE TRADING AND CONSTRUCTION an additional HSE-survey of the landfill site in accordance with the environmental clearance by the Authorities.

4.3.4. LEACHATE TREATMENT UPGRADE OPTIONS

BIOLOGICAL TREATMENT

A biological treatment of leachate comprises a pre-denitrification tank followed by a nitrification tanks. These process vessels hold a blend of water and microorganisms (activated sludge). A membrane system, a so-called Ultrafiltration, is placed behind the bioreactors and “collects” the microorganisms, keeping them all in the bioreactors. The activated sludge works on the contaminants in the wastewater (landfill leachate), supported by a highly efficient oxygen transfer system, a state-of-the-art jet aerator unit which provides oxygen for the biodegradation of COD/BOD and ammonia. Thereby all biodegradable organic material can be turned into CO2. The result is a high quality treated effluent.

A further description of the biological process follows below (see also Figure 28):

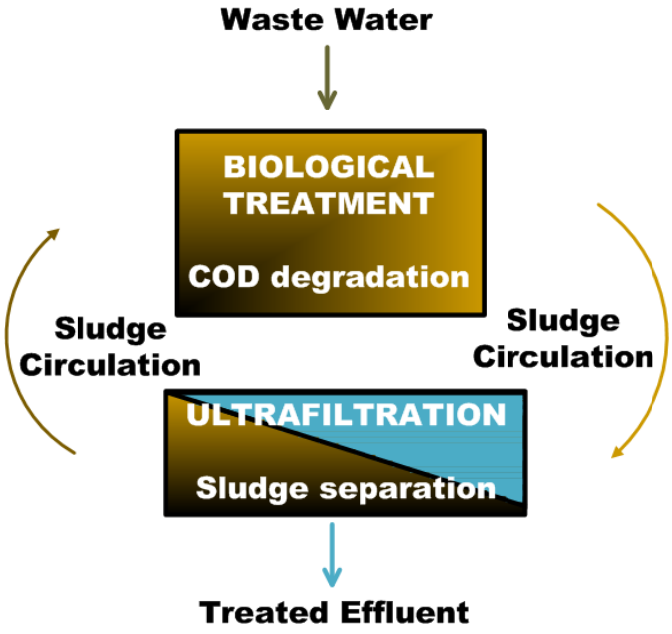


Figure 28: Combination of biological treatment and UF for sludge separation (Reference: WEHRLE)

The first biological process step is pre-denitrification. This is a natural process taking place under anoxic conditions in a denitrification vessel using readily biodegradable organic material. To increase the rate of denitrification an external carbon source (e.g. acetic acid) can be added. Heterotrophic bacteria utilise this carbon source to reduce nitrate to molecular nitrogen. A high rate of

denitrification is normally required to meet the total N discharge consent. However, before this comes into effect the plant will denitrify using the available BOD in the leachate.

Denitrification

$$4\,NO_3^- + 5\,C + 4\,H^+ \xrightarrow{\text{heterotrophic bacteria}} 2\,N_2 + 2\,CO_2 + 4\,H_2O$$

The denitrification process saves energy and chemicals (e.g. caustic soda) otherwise required for stabilizing the pH. The biodegradable matter which is consumed in the denitrification process does not need to be oxidised in the later nitrification process. This reduces aeration energy consumption. In addition, as alkalinity is recovered during denitrification, this eliminates the requirement for caustic soda for pH-stabilization.

The activated sludge is then transferred to the nitrification tank. In the nitrification tank ammonium is oxidized in two stages: First, ammonia-oxidizing bacteria (nitrosomonas) oxidize ammonia to nitrite. Then nitrite-oxidizing bacteria (nitrobacter) oxidize nitrite to nitrate. In the same reactor COD is biologically removed.

Nitrification

$$2\,NH_4^+ + 3\,O_2 \xrightarrow{\text{Nitrosomonas}} 2\,NO_2^- + 2\,H_2O + 4\,H^+$$

$$2\,NO_2^- + O_2 \xrightarrow{\text{Nitrobacter}} 2\,NO_3^-$$

The concentration of oxygen in the nitrification tank should range between 1–3 mg O_2/L. An aeration system, located inside the bioreactor, continuously aerates the biomass with air being provided by an external blower. The dissolved oxygen (DO), pH and temperature in the bioreactor are monitored and used to control operation of the blowers to maintain the desired residual DO. This ensures efficient operation with lower expenditure on energy.

By definition, all biological treatment processes create excess ‘sludge’. The latter, in fact, is bacteria/biomass that has grown during the waste water treatment process and is a by-product of the bio-oxidation of carbohydrates contained in the waste water. The excess sludge needs to be removed on a regular basis to maintain the desired sludge concentration and sludge age.

ULTRAFILTRATION

The ultrafiltration plant is based on a side-stream crossflow membrane filtration process by using true UF tubular membrane modules. The use of the tubular membrane modules (see Figure 29) provides the complete retention of biomass.

The ‘mixed liquor’ of activated sludge and effluent is pumped from the bioreactor through the tubular membranes in order to separate the treated waste water from the activated sludge. All bacteria and any COD from suspended solids material, plus macro-molecules and colloidal matter, are safely retained within the system and are continuously fed back, as ‘retentate’, into the bioreactor.

The tubular membrane modules allow the operation at much higher mixed liquor solids concentration (MLSS) compared to other membrane systems. This can provide major cost savings, e.g. smaller bioreactors and reduced volume of the waste sludge to dewater.

Figure 29: (left) Tubular membrane module (Photo: WEHRLE)

Figure 30: (right) UF-loop with dedicated circulation pump (Photo: WEHRLE)

The UF system typically consists of 2 - 6 tubular membrane modules connected in series to form a UF-loop. The complete ultrafiltration plant can comprise several UF-loops operating parallel, depending on the required throughput.

Each UF-loop has a dedicated circulation pump (see Figure 30) sized to provide the required crossflow velocity along the membrane, to reduce fouling and maintain a high permeate flux.

The side-stream crossflow process offers very high permeate flux, compared to other membrane systems, thus requiring much less membrane area and substantial cost savings from future replacements.

Occasionally the UF membrane modules will need to be rinsed or cleaned. This can be achieved via the wash pump by using water or permeate stored in the wash tank. Any chemicals needed to clean the membranes can be dosed into the wash tank. The rinse and clean procedure are automated and requires only minimum attention. The individual UF loops can be rinsed or cleaned while the remaining loops are in operation.

Compared to other membrane systems (e.g. with submersible membranes), the crossflow ultrafiltration plants are designed as a closed loop systems and are located inside a building or a container. Consequently the operator does not get in contact with any activated sludge or waste water during the operation and cleaning procedure, and no aerosols are produced.

Figure 31 shows the typical set-up of a Membrane Bio Reactor (MBR) process beginning with a balancing tank, followed by the bioreactors. Form the bioreactors, the activated sludge is pumped

through the manifold of the UF loops. Each of the UF loops circulates the activated sludge over the UF membranes which are connected in series. The released flow from the UF membranes (the so called retentate) is recirculated back into the biology. The solids-free permeate is discharged as clean effluent. Figure 32 shows an MBR plant for leachate treatment.

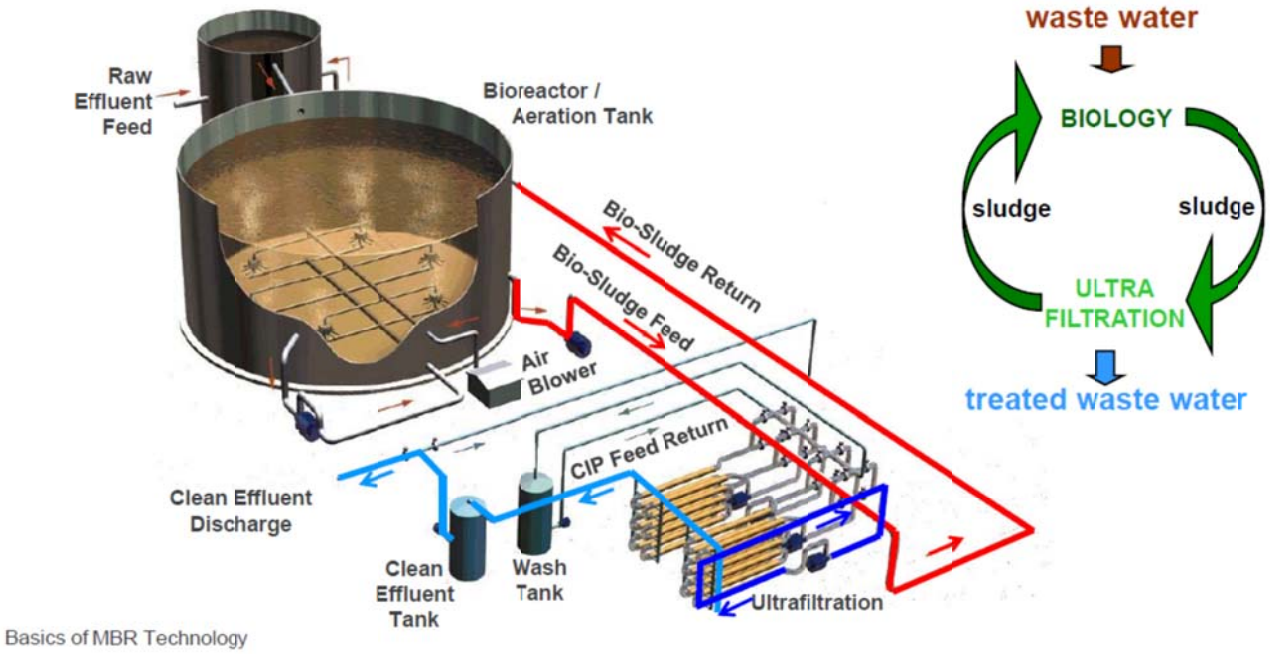


Figure 31: Membrane Bio Reactor process (Reference: WEHRLE)

Figure 32: Membrane Bio Reactor plant (Reference: WEHRLE)

5. IMPLEMENTATION OF A WASTE TREATMENT CONCEPT FOR THE PROVINCE OF LAGUNA

This report is based on information gathered during the on-site meetings in the Province of Laguna in April 2017 and February 2018, information provided by GIZ Urban Nexus, ICLEI SEAS, local stakeholders and literature.

During the analysis of the data it became evident that customized concepts have to be developed for the individual LUGs, for clustering proposals as well as for the existing waste disposal sites.

In the following, centralized solutions for the urban areas and decentralized concepts for the rural areas shall be depicted as well as the processes and technologies involved and the CAPEX and OPEX for these processes will be presented.

The basic idea for a waste management strategy in the Laguna Province was that there is *one* general treatment concept that comprises several process stages. These stages can be combined in such a way that each LGU gets the best-suited solution. Thus one concept can be used to cater for the different needs of the individual LGUs. For example it would make sense to have a simple and inexpensive solution nearby (= decentralized) for a LGU that has

- low waste production
- and a remote location
- or/and a geographically difficult (e.g. hilly) location
- or/and poor infrastructure.

Whereas communities with a

- large waste production
- close to an existing waste treatment facility / landfill site
- good infrastructure

could cluster and invest together (= centralized) in technically advanced waste treatment systems with energy recovery form the treatment products.

Contrary to the initial idea of implementing a central waste treatment concept at the San Pedro landfill site, the landfill operator presented a different approach for the treatment of MSW during another site visit in February 2018. Thus, for San Pedro, the implementation of a MBT concept (as presented as following) is no longer feasible but the concept itself is, of course, conferrable to other sites.

Figure 33 depicts the different process stages that are part of such a waste treatment concept. Each stage will then be described in more detail in the following chapters. The main statement is the differentiation between centralized and decentralized concepts and different technological levels. So Figure 33 shows:

- Decentralized concept: Locally-built, technically simple, for low waste quantities (see chapter 5.1.1)
- Decentralized concept: Technically more sophisticated, for medium waste quantities (see chapter 5.1.2)
- Centralized concept: Treatment plant for several cities, for larger waste quantities (see chapter 5.2)
- Centralized concept: Energetic utilization of high calorific fraction and RDF (see chapter 5.3).

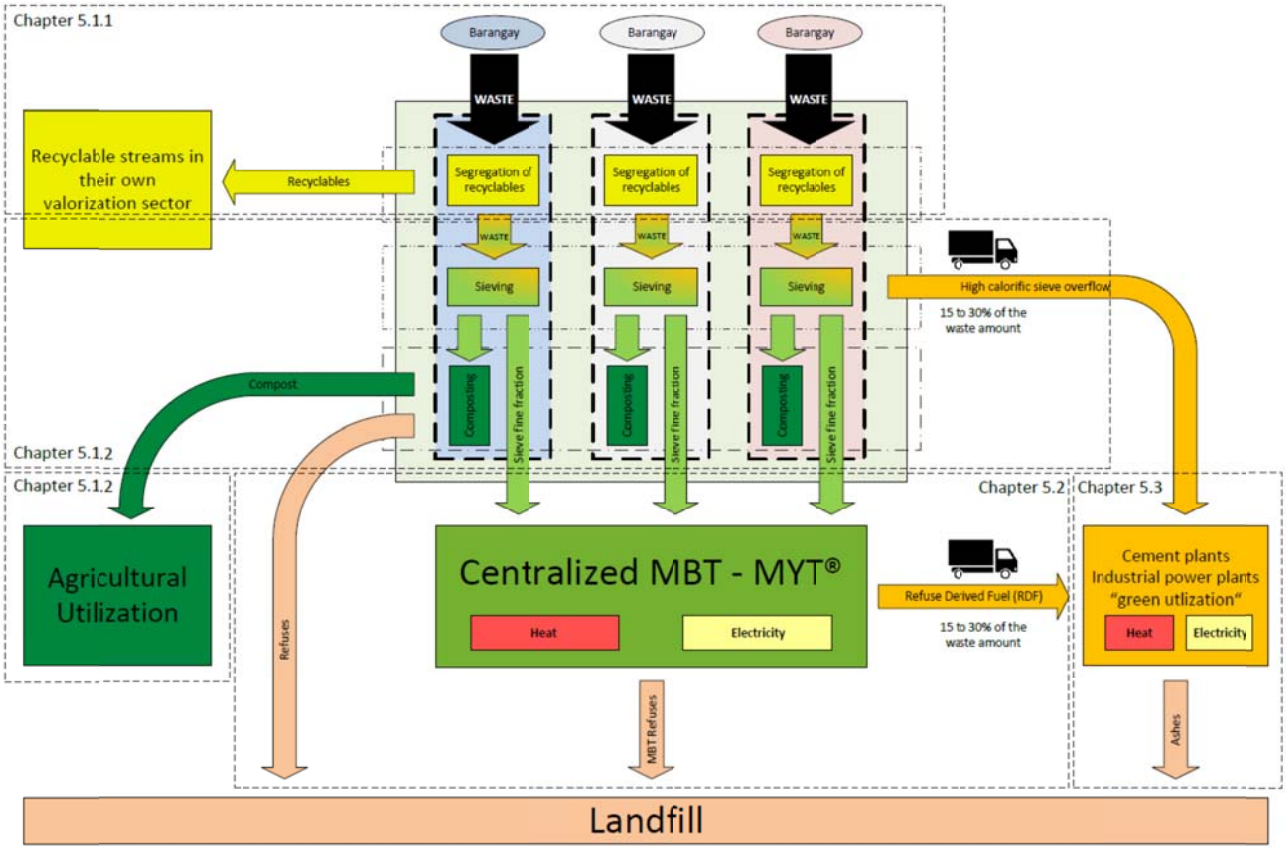


Figure 33: Waste treatment concept for the Province of Laguna (Reference: WEHRLE)

5.1. DECENTRALIZED WASTE TREATMENT (IN RURAL AREAS WITH SMALL / MEDIUM WASTE GENERATION RATES)

For selected cities of the Laguna Province the waste management concept allows for one central station for the mechanical-biological treatment of waste and energy recovery which serves a number of LGUs.

Yet due to the spatial distances and the difficult transport conditions, transport of organic-rich and moistures / wet waste before separation can be costly (e.g. only small waste trucks due to narrow roads) and can be environmentally harmful (e.g. leakage of leachate from the waste trucks). Thus all technically simpler steps of the waste processing should take place decentralized in the individual LGUs.

5.1.1. CONCEPTS WITH SIMPLE ON-SITE MEASURES

For LGUs with a low waste production in remote areas and poor facilities on site (e.g. with non-existent or very basic machinery) only simple measures for waste separation and waste processing should be used.

Here in particular the topic of "segregation at source" plays an important role. Organic waste can easily be separated in every household and can be converted into compost either by means of a small garden composter. Alternately, the LGUs could install simple devices such as composting drums for composting in their local communities. Such simple machinery could even be manufactured locally or made from scrap material. Thus, the organics could be transferred into fertilizer which is directly returned to the land.

Recyclables (PET bottles, metals, glass etc.) should also best be separated on a household level. For their disposal small recycling centers can be set up locally from where they can be transported to the respective recycling facilities. Any revenue from the recycling of materials could be reinvested in the LGUs.

Thus, only the remaining waste free from organics and recyclables needs to be transported to far-away landfill sites.

The first step could be the installation of a simple mechanical waste pre-treatment for 200 tons/day. Yet in order to keep the scavengers in work, the manual sorting of valuable materials by scavengers could still take place before this pre-treatment, at the waste acceptance. Thus, they could keep their income and at the same time could help to avoid some problems in the proposed mechanical pre-treatment by sorting out problematic compounds.

The pre-treatment could as a minimum comprise a shredder followed by a disc separator in order to fractionate the waste. The separator produces two streams: a large fraction >80 mm that mainly consists of plastics and can be considered as RDF (refused derived fuel) (see Figure 34).

The small fraction <80 mm, containing the organic material, would then be landfilled.

The fractionation of the waste in such a way already greatly reduced amount of waste to be landfilled and its smaller size + homogeneous size distribution allows optimal compacting. This part requires only electricity for the machines and does not produce waste streams.

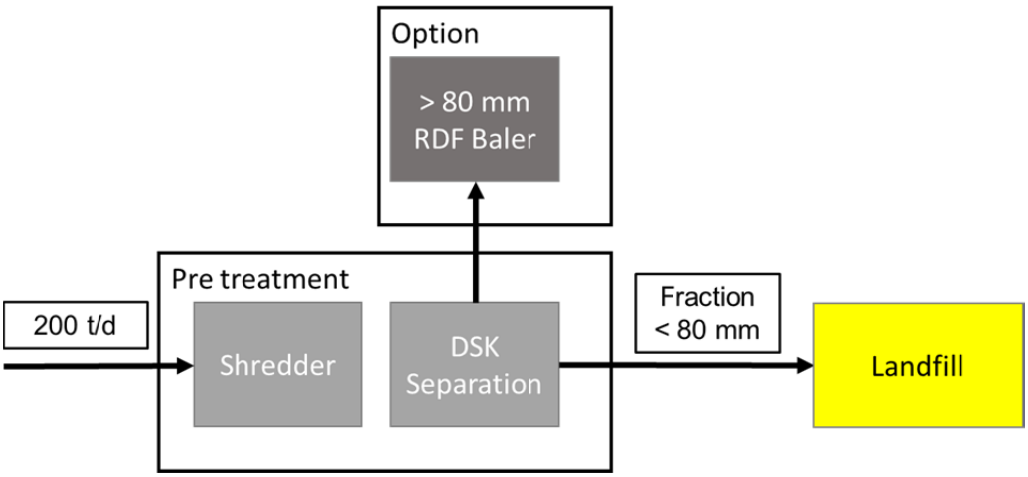


Figure 34: Possible concept implementation (Reference: WEHRLE)

Key data pre-treatment unit:

From the data collected during the site visit, the following design data for such a pre-treatment were deducted:

1 Pre-shredder + magnet station

1 Disc screen + manual sorting unit

Footprint:	approx. 1,000 m²
Input:	approx. 200 tons/day approx. 70,000 tons/year (MSW)
Output:	approx. 70 tons/day approx. 25,000 tons/year (fraction >80 mm; RDF/Recyclables) approx. 130 tons/day approx. 45,000 tons/year (fraction <80 mm; bio fraction).

5.1.1.1. EXAMPLE OF SHREDDER

The proposed type of shredder is for shredding different materials such as domestic waste, residual waste, mixed construction waste, etc. with low noise generation and with low wear of tools. Due to the tool heads with alternating interlock and grip, it provides a well draw-in and self-cleaning behaviour even for material difficult to shred.

The landfill material is filled into the shredder by a wheel loader, shredded by the tools and discharged almost equally by a feeding conveyor with smooth belt and skimmers and brought to the magnet station. The feeding conveyor has an approx. 17° inclination, so it is possible to use a smooth belt. It guarantees that even under extreme conditions the space below the conveyor belt

is almost free of wet dribbling. The top roller of the conveyor belt consists of chromium-nickel steel. A tipping hopper is included, so it is possible to load the shredder with a wheel loader. The size of output material of the shredder is smaller than 250 mm.

Figure 35: Shredder (Photo: EuRec)

5.1.1.2. EXAMPLE OF DISK SEPARATOR

The proposed disc separator type is a low-maintenance, high-performance equipment suitable for the screening of difficult materials as well. It is characterized by an extreme compact constructive design. Special devices allow reliably to separate different fractions from the material flow (>7,5 mm - <50 mm). Possible adjustments of screen deck inclination have an effect on the residence time of material and the screening result.

The screen shafts are equipped with patented sleeves and screen discs. The shafts provide an effective self-cleaning behaviour, so there won't be apprehensive large-scaled material wind-ups anymore.

The disc separator is installed here for separating of the organics as well as the heavy fine material, which is smaller than 80 mm. The material stay above the screening deck is then only the fractions with a size between 80 and 250 mm, which contain high heat value so that can be further reused as RDF.

The accelerating conveyor of the disc separator guarantees an optimal feeding of the landfill material to the screening deck. There it is accelerated by the patented screen shafts; from shaft to shaft the material is shaken up. By this, organic material or its remains are screened optimally. Fine grain (<80 mm) and half rotted organics ends up on the collecting conveyor installed below the screening deck and is discharge by the short and crosswise arranged transport conveyor. Here, a long dump belt can be installed that throws off the fine material into a provided container or set it up as conical debris, and then can be transported into the biological dryer. Further patented devic-

es of disc separator avoid rewinding and adhesion to a large extent and thus guarantee an almost trouble-free operation.

Figure 36: Disc Separator (Reference: EuRec)

5.1.1.3. COST ESTIMATION FOR CONCEPTS WITH SIMPLE ON-SITE MEASURES

Table 9: Cost estimation

1	**CAPEX** **Shredder, metal separation, disc separator** (Option Baler)	USD	**1,000,000** (700,000)
2	**OPEX** (without refinancing)	USD/year	**270,000**
3	**Revenues**	USD/year	**110,000**

5.1.1.4. POSSIBLE LAYOUT

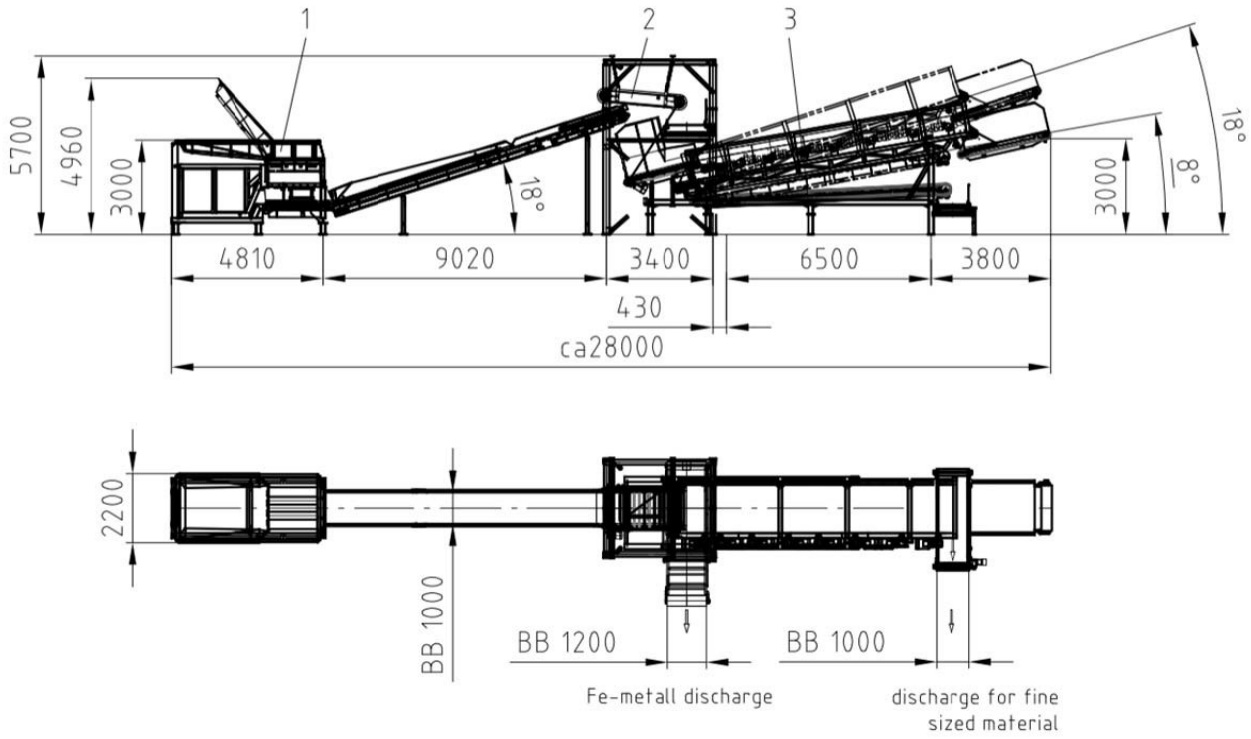


Figure 37: Layout: Shredder (1) – Magnet station (2) – Disk screen (3) / (Reference: EuRec)

Figure 38: EuRec reference plant Vinh Long, Vietnam: Shredder / Magnet station / Disk screen / Manual sorting unit (Reference: EuRec)

5.1.2. CONCEPTS WITH SIMPLE TREATMENT PLANTS

In LGUs with a medium waste production and an improved infrastructure it is also the 'segregation at source' that needs to be strengthened first:

Separation of recyclables (PET bottles, metals, glass etc.) in the households shall be the main focus of improvement measures. Like in the small communities, the recyclables can then be delivered to central points of the LGUs (e.g. recycling yard) in order to generate monetary revenues from easily separable and recordable 'recyclables'.

Embedded in this recycling measure, local workers can be given an employment and income perspective to address widespread scavenging.

The presorted waste is then screened. It is reasonable to assume that the waste contains a significant amount of the coarse fraction containing the high-calorific material. This material leaves the screen with the overflow as High Calorific Fraction (HCF) and can be fed to a cement kiln or an industrial power plant. Experience has shown that the HCF constitutes between 15 and 30 % of the waste.

Additionally, the waste passes the magnetic separation, where the remainder of the ferrous material is removed.

The remaining waste can then be composted decentralized in the individual LGUs. This would help to produce a high-quality compost which can be used locally and does not require much environmentally harmful transport.

As an alternative to composting, the technically more demanding box fermentation can also be used in the individual LGUs. Such a box fermentation generates in a first step valuable biogas from organics that are still in the waste. The biogas can be used in form of electrical energy. The output from the box fermentation can then be composted and again be returned to the nutrient cycle.

In this concept only a small amount of remaining waste needs to be landfilled on a centralized landfill site.

Composting allows stabilization and hygienization of the waste. During the thermophilic phase, the aerobic microorganisms oxidize the organic matter by mineralizing the readily degradable fraction. Thus the matter is stabilized. Because the material is heated by the biological process up to 70°C, most pathogenic germs are destroyed.

The following Figure 39 illustrates the proposed concept with simple treatment plants.

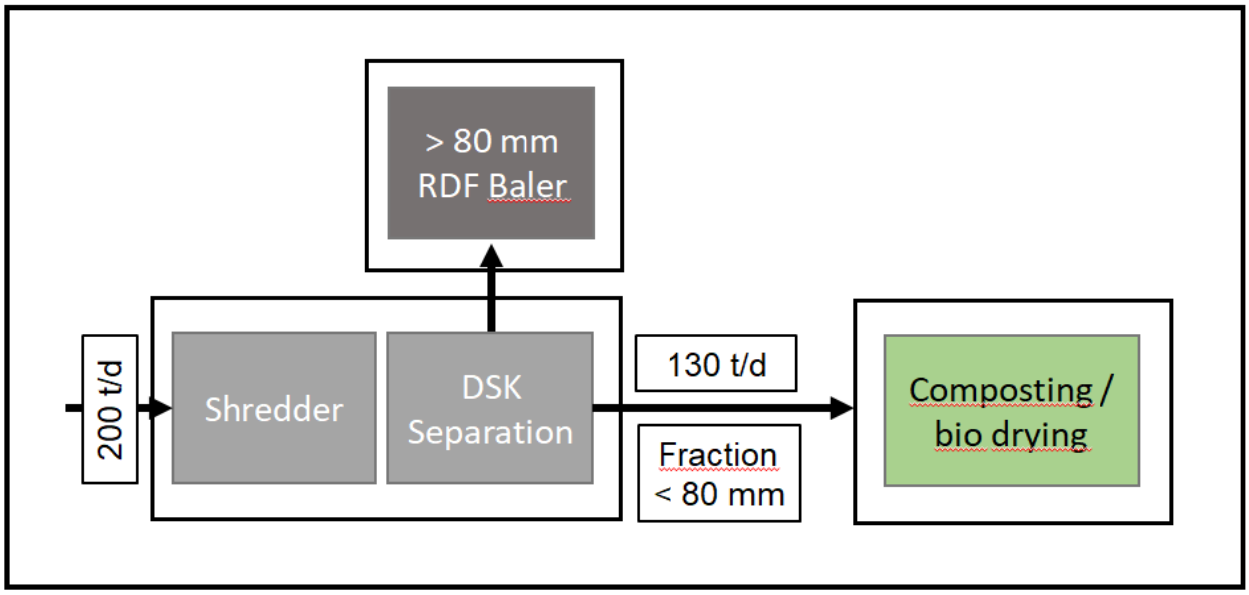


Figure 39: Possible concept implementation (Reference: WEHRLE)

5.1.2.1. EXAMPLE OF BIOLOGICAL DRYING SYSTEM IMPLEMENTED IN GERMANY: BOX DRYING AND COMPOSTING UNIT

Biological drying is a method to drastically reduce the waste's water content thus depriving the microorganisms the water required for their metabolism and the breakdown of the organic material.

After a drying, the waste can be stored, transported and used on demand without risking changes of the material and its properties due to biochemical reactions.

The drying is done biologically in an energy-efficient and economical way with the energy inherent in the waste. In tightly closed tunnels (see Figure 40, Figure 41 and Figure 42) microorganisms which are already present in the material metabolize the organic matter, which is still present in the material pores e.g. as process water, resulting in CO_2, water and heat. The air required by the microorganisms for the breakdown of the organic material is introduced into the tunnels via floor aeration systems. To enhance their metabolism and to control the temperature inside each tunnel, the air supply into each tunnel is automatically regulated and controlled, the produced heat evaporates the moisture of the processed waste. Due to optimized conditions a reduction of waste water contents to less than 25 % is achieved without requiring any external heating / energy input.

Because the waste is prone to develop strong malodours during the drying, all tunnels, belts, machines and aggregates are fully closed and their exhaust air is extracted and sufficiently treated to minimize the emission of odours into the environment to an absolute minimum.

In the proposed technical example a tunnel technology in closed reactors is included. The entire process for drying should take ~21 days. In total 12 tunnels are needed to have enough time for shifting the drying material.

Tunnel technology

The process is carried out in a closed concrete reactor with rooftop from a semi-transparent layer or concrete ceiling. The reactors are 20 m long and 8 m wide. Each reactor can take up to 200 tons of waste. To achieve the required throughput 12 drying reactors are required. This system as a closed system requires a biofilter for process air treatment.

Figure 40: Example for closed waste bio-drying system (Reference: Probios)

Figure 41: Example for closed waste bio-drying system (Reference: Probios)

Figure 42: Example for closed waste bio-drying system (Reference: Probios)

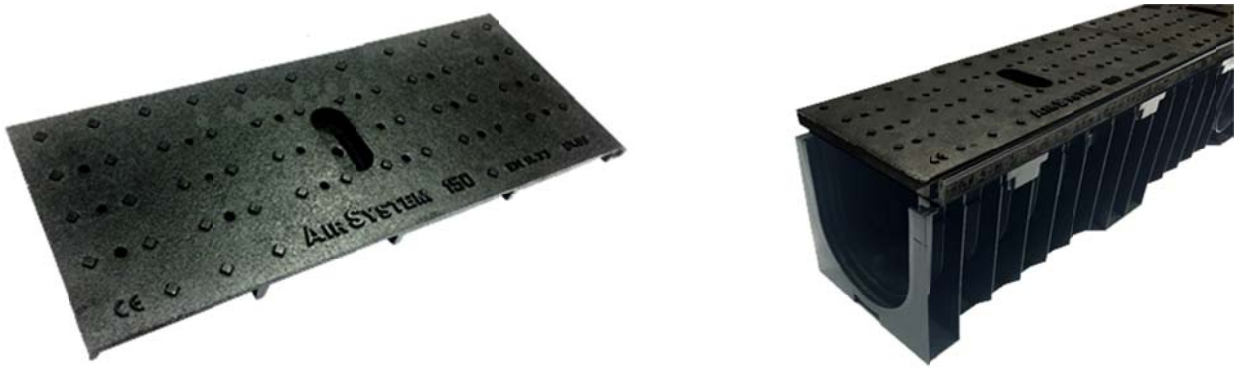


Figure 43: Floor aeration system (Reference: Probios)

Advantages of closed waste bio-drying system:

- Process stability regardless of outside weather conditions
- Almost no malodour
- No animals (rodents, birds)
- Not much area needed
- Durability.

Closed waste bio-drying system consists of:

- Air supply system (blowers, automation boxes)
- Aeration system (under floor piping)
- Basic wiring
- Probes (temperature)
- Control system
- Staff training.

Process control

The bio drying system is controlled via a process control system. The performance is controlled based on read outs of temperature probes for most economical and effective bio-drying effect.

The control panel is located in a separate building or a booth, it can also be controlled via mobile device app.

Figure 44: Control room (exemplarily)

5.1.2.2. COST ESTIMATION FOR CONCEPTS WITH SIMPLE TREATMENT PLANTS

Table 10: Cost estimation

1	**CAPEX Tunnel Drying Composting** Mechanical and Electrical Installation Costs for civil works **SUM**	USD	 1,300,000 900,000 **2,200,000**
2	**OPEX** (without refinancing)	USD/year	**210,000**
3	**Possible Revenues** (through compost selling)	USD/year	**180,000**

5.1.2.3. POSSIBLE LAYOUT

An exemplary possible layout of the proposed bio-drying system is shown in Figure 45 below.

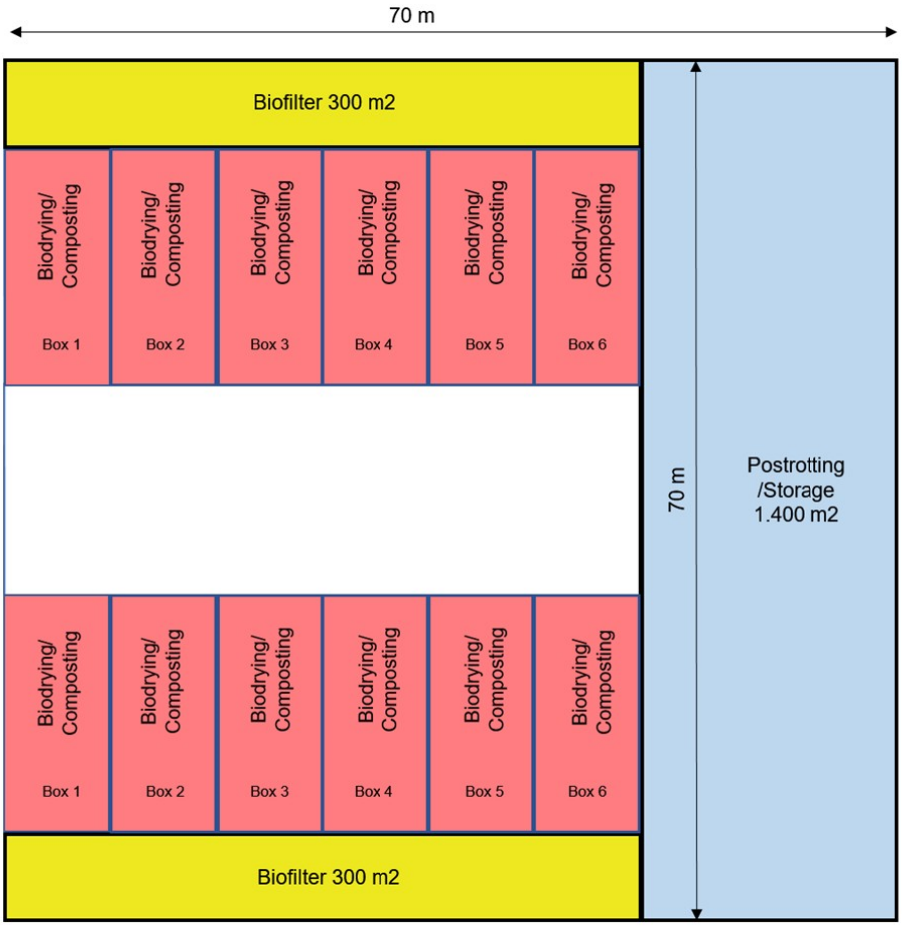


Figure 45: Layout of bio-drying system (Reference: Probios)

5.2. CENTRALIZED WASTE TREATMENT FOR THE PROVINCE OF LAGUNA FOR GENERATING HIGH-QUALITY SECONDARY FUELS

5.2.1. APPROACH: CLUSTERING

The original approach “CLUSTERING” would have allowed to exploit synergies in waste management. A centralized mechanical-biological waste treatment plant (MBT) would have been made part of the waste management concept instead of the decentralized composting / fermentation (as described in the chapters 5.1.1 and 5.1.2).

Figure 46 shows selected towns in the Province of Laguna that had been eligible for a central MBT waste treatment facility (MBT) because of their amounts of waste and their location.

Generated waste in selected Laguna Province Cities (largest six)

City	(tons/day)	(tons/year)
Santa Rosa	250	90.000
Calamba	190	70.000
Cabuyao	180	65.000
San Pedro	165	60.000
Binan	120	45.000
San Pablo	114	40.000
Total	**1.019**	**370.000**

Reference: Provincial 10-Year Solid Waste Management Plan - Province of Laguna 2015

Figure 46: Map of the Province of Laguna and generated waste in selected cities (Reference: Provincial 10-Year SWMP 2015-2024 Province of Laguna)

Table 11: Sample Cluster formed on SWM (Reference: Sustainable Solid Waste Management through Clustering; Workshop on SWM, April 27-28 2017, Santa Cruz, Laguna)

REGION	Name of Cluster/ Facility	Type of Partnership	Partners	Type of Facility/ Location	Legal Instrument/ Date	Status
IVA	Pilotage SLF, San Pedro Laguna	Private Enterprise utilized by LGUs	San Pedro, Sta. Rosa, Los Banos and Carmona	SLF with MRF	Contract	Operational

Source: EMB Regional Offices

Table 11 shows an example of a cluster (according EMB Regional Offices) for Region IVA, which includes the cities of San Pedro, Santa Rosa, Los Banos, and Carmona. The name or location of the facilities for this cluster is Pilotage SLF San Pedro Laguna.

In this report an exemplary concept for such a centralized facility at the San Pedro site shall be described based on the original clustering approach of the LGUs Santa Rosa, Calamba, Cabuyao, San Pedro, Binan and San Pablo. Yet this concept for a centralized facility could also be applied at other clusters within the provinces of the Philippines.

5.2.2. MECHANICAL-BIOLOGICAL TREATMENT WITH MYT® PROCESS

The output of the segregation and separation steps as described in the previous chapters is the sieve throughput, a wet fraction which contains all the organic waste. Instead of composting, this organic fraction can be treated very effectively in an MBT-plant.

An ideal process for this MBT plant would be the so-called Maximum Yield Technology (MYT®) process. In the MYT® process the readily soluble organic constituents are literally washed out of the waste. This washing liquid is then converted into biogas in an anaerobic fermenter. The biogas can be utilized directly on site in a combined heat and power plant (CHP) to provide the electrical energy required for operating the MBA. Surplus electrical energy can be fed into the grid. The waste heat of the CHP is used to heat the anaerobic fermenter stage.

The waste remains for about 2-3 days in the so-called multi-zone reactor (MZR) for the above described washing procedure. During this time biodegradation of easily decomposable waste takes also place and increases the organic content of the “washing water”. The non-soluble waste that leaves the MZR is dewatered and then transformed in further processes into waste derived fuels.

Depending on the degree of mechanical pretreatment, the output of the MYT® process ranges between 15 and 30 % of the raw waste quantity. Treating the MSW with the MYT® process significantly increases the calorific value (CV) of the waste, and this naturally has a very favorable effect on the use of this so-called refuse derived fuel (RDF) as a substitute fuel.

The process water of MYT® process such as the effluent leaving the fermenters, for example, is treated in an associated wastewater treatment plant to an extent that it can be reused in the MBT plant.

This waste water treatment plant could also be designed to treat the leachate from the adjacent landfill site.

5.2.2.1. GENERAL MYT® PROCESS DESCRIPTION

The MYT® process is a multiple-stage process for the treatment of municipal solid waste. The process is especially suitable for wet, waste rich in organics. After a mechanical pre-processing the waste is conveyed to a 2-stage biological process. In the first stage of this biological process readily biodegradable organic matter is hydrolysed aerobically and all water soluble compounds are washed out (percolation). The heavily loaded process water is then sent to the second stage, the anaerobic fermentation, where anaerobic microorganisms transform the organics into energy-rich biogas. The effluent from the anaerobic digesters, the so-called digestate, is returned partly to the percolation process and partly discharged to a waste water treatment process. The constituents of the waste which are not biodegraded within the 2-days the waste remains in the percolators ensure that the waste still contains structure material which is advantageous for the percolation.

After the percolation stage the waste is mechanically dewatered and biologically dried. A separation process fractionates the dried waste. These fractions represent the different types of RDF with their different energy contents. The advantage of treating municipal solid waste by a percolation unit is that through this process the caloric value is increased, while at the same time the waste volume is reduced and in parallel biogas is produced. This is especially important when the waste is supposed to be used as a form of fuel. This process is suitable for large volumes as the retention time in the percolators is very short. Since MYT® is a modular technology, a MYT® plant can easily be expanded to meet future demands on throughput capacity.

The following process flow diagram illustrates the MYT® process which has been built at the Kahlenberg landfill site in Germany.

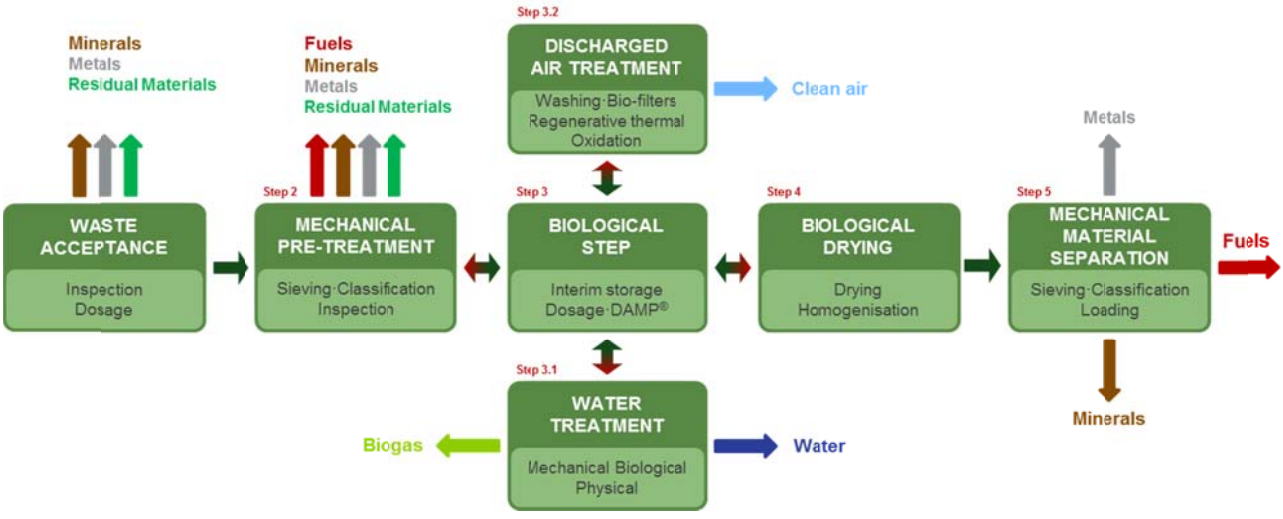


Figure 47: Flow scheme of the MYT® process “MBT Kahlenberg“ (Reference: WEHRLE)

The MBT plant of the ZAK (Zweckverband Abfallbehandlung Kahlenberg) in Germany comprises five treatment steps. First (Waste Acceptance) the waste is delivered to a waste acceptance hall where first of all the bulky waste is picked out and separated by a loader to protect the subsequent machinery. In the second step (Mechanical Pre-Treatment), bags are ripped open, then the waste is treated further by screening, metal separators and manual sorting in order to remove either

scrap metal or toxic/harmful substances. These first two steps are mechanical processes. They are followed by biological step, the core step of the MYT® process (Biological Step): The waste enters a so called Multi Zone Reactor (MZR). In the MZR the waste is mixed and soaked with water. The aerobic process conditions in the MZR are stated in the process name DAMP®, which stands for Defined Aerobic Mixing Process. This operation is aiming at homogenizing the waste, disintegrating the remaining material (e.g. packaging, diapers) and hydrolysing the organic fraction. The organic enriched process water is conditioned and fed into an anaerobic reactor for biogas production. The effluent from the anaerobic process is purified to meet the discharge limits. The leached waste is released from the MZR after about 2-3 days, is dewatered and the solids are transported to the halls for the biological drying (Biological Drying). There the dewatered material is aerated in drying tunnels., The heat produced by the aerobic microorganisms in the waste is sufficient to dry off the waste, so no external heat is required. The material leaving the biological drying is stabilized and - with a moisture content of about 10 % - presents Refused Derived Fuel (RDF). The final treatment step (Mechanical Material Separation) allows the classification of the RDF in order so produce various fractions with specific properties (e.g. size, calorific value, chloride content).

The following figures show the key components of the plant “MBT Kahlenberg”:

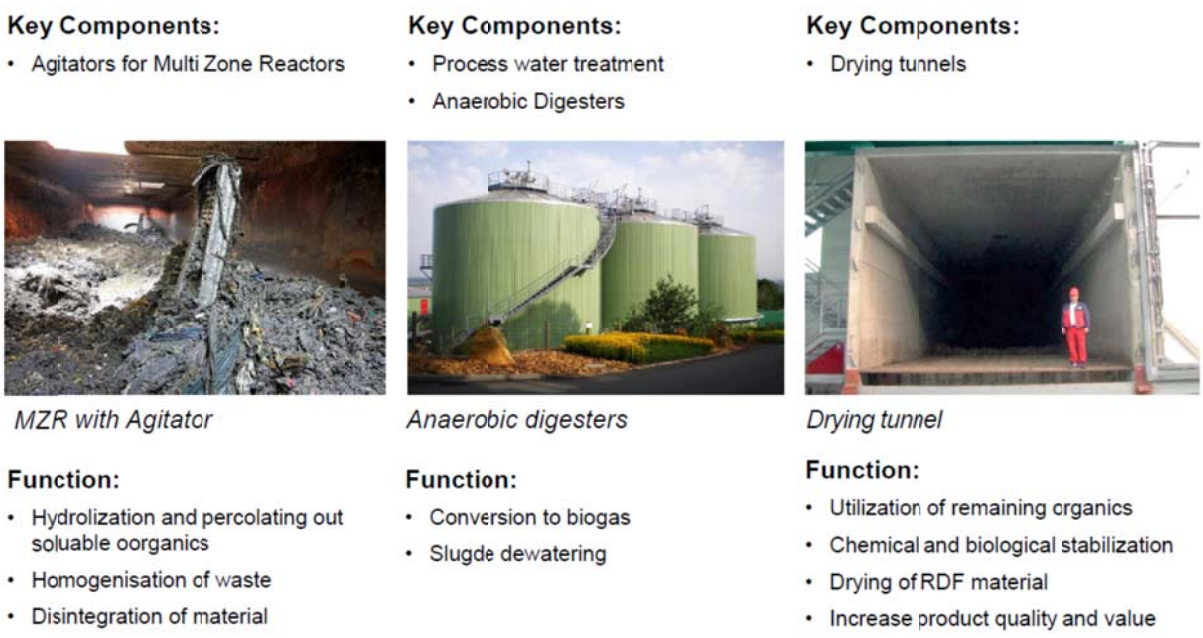


Figure 48: Key components of the “MBT Kahlenberg“ (Reference: WEHRLE)

Key Components:

- Gas holder, flare

Membrane gas holder and flare

Function:

- Gas storage

Key Components:

- Gas holder, flare

CHP unit

Function:

- Electricity generation

Key Components:

- Membrane filtration

Ultrafiltration

Function:

- Water purification

Figure 49: Key components of the “MBT Kahlenberg“ (Reference: WEHRLE)

Refuse Derived Fuel (RDF) can be used e.g. in:

- Cement kilns
- Paper mills
- Heat and power stations

Figure 50: RDF utilization options (Reference: WEHRLE)

5.2.2.2. PROPOSED MYT® TECHNOLOGY FOR EXAMPLE "LAGUNA" IN BRIEF

The following Figure 51 illustrates the proposed concept with an adapted MYT® process.

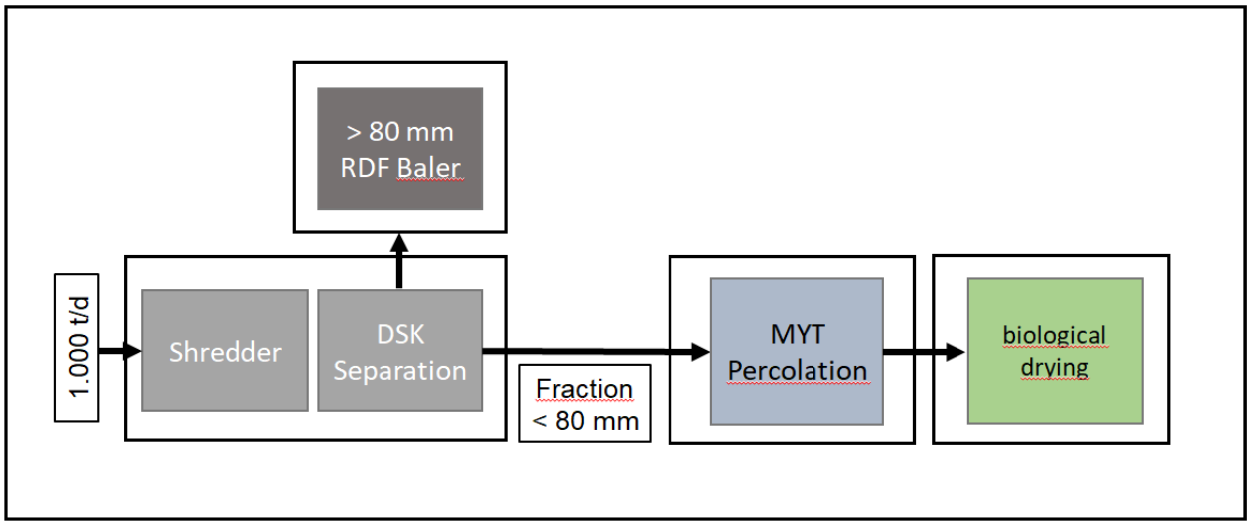


Figure 51: Possible concept implementation with adapted MYT® process (Reference: WEHRLE)

DAMP® Reactors

In order to be able to implement the MYT® process in the example "Laguna", is has to be customised to the specific needs of the site.

Figure 52: Defined Aerobic Mixing Process (Photos: WEHRLE / ZAK)

The biological step is the core of the MYT® process and includes the most innovative process: DAMP®. DAMP is the short form for Defined Aerobic Mixing Process.

In this process the waste is continuously fed into horizontal reactors, the DAMP® reactors, where it gets disintegrated and homogenized by large, robust agitators, while process water is added. The agitators on the one hand support the transfer of the material through the reactors and on the other hand partially crush the material to allow the process water to get in maximum contact with the material.

The percolation water washes out soluble organic matter from the waste. This heavily loaded process water is digested anaerobically in a separate fermentation stage to gain biogas from the organic rich feedstock.

After the waste has been treated for 2 - 3 days in the DAMP® reactors, the solid material is mechanically dewatered to fulfil the moisture requirements for further treatment in the downstream biological drying.

Biological Drying

One advantage of the RDF produced by MYT® is its biochemical stability. This means that the material can be stored and transported and used on demand without risking changes of the material and its properties due to biochemical reactions. To achieve this, the material's moisture content is drastically reduced, to deprive any microorganisms of the water required for their metabolism.

The drying of the material leaving the DAMP® process is done biologically in an energy-efficient and economical way using solely the heat generated by microorganisms: Within tightly closed concrete tunnels (Figure 53) microorganisms, which are already present in the material, metabolize the organic matter still present in pores, e.g. as process water, producing thereby CO_2, water and heat. To enhance their metabolism and to keep the temperature inside each tunnel within a desired range, air is supplied to each tunnel. This is automatically controlled. The generated heat is sufficient to evaporate the remaining humidity of the waste and to dry it off. Thereby moisture contents of <25 % are achieved with no external heat requirements.

Many years of experience with this technology at the MYT® Plant Kahlenberg helped to fine-tune this process so that it finally reached today's much improved condition.

Because of the high potential of odour emissions in drying step, all tunnels, belts, machines and aggregates are fully closed and their exhaust air is extracted and sufficiently treated to minimize the emission of odours into the environment to an absolute minimum.

Figure 53: Concrete tunnels in the biological drying (Reference: ZAK)

5.2.2.3. PROPOSED MYT® PLANT LAYOUT FOR EXAMPLE "LAGUNA"

In Figure 54 the proposed MYT® plant is shown. For the proposed MYT® plant an area of 4.5 ha is required.

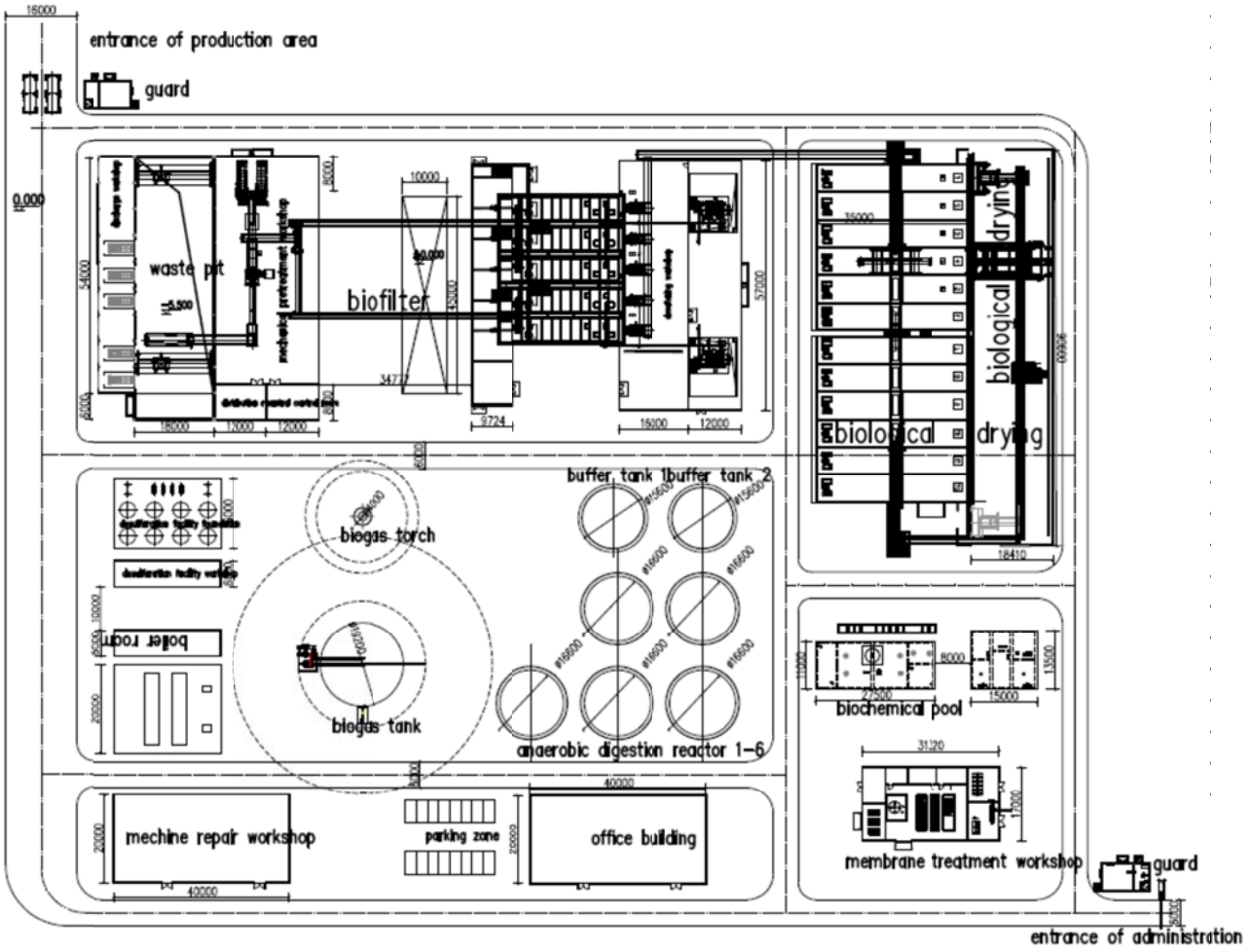


Figure 54: Exemplarily layout for proposed MYT® plant (Reference: JS WELLE)

5.2.2.4. PROPOSED MYT® PLANT FIGURES FOR EXAMPLE "LAGUNA"

In the following the main components, the output and key figures of the proposed MYT® plant are listed:

Main components

- Defined Aerobic Mixing Process (DAMP®)
  - multi zone reactors
  - dewatering presses

- Anaerobic stage
  - anaerobic reactors
- Waste air treatment
- Biogas utilization
  - co-generation machines
  - gas holder
  - biogas desulphurisation
- Followed by treatment of process water
  - by aerobic + membrane method (MBR)
- Key data biological drying:
  - tunnel drying as described
  - approx. 12 tunnel boxes
  - wheel loaders for tunnel charging
  - input mix: approx. 550 tons/day → approx. 193,000 tons/year (@ Ho 9 MJ/kg)
  - energy consumption for biological drying approx.10 kWh/ton input treatment plant.

Output of proposed MYT® process (inclusive drum screen overflow >80 mm)

- RDF: approx. 520 tons/day (DS >85 %; approx. 17 MJ/kg); selling to cement facilities, paper mills, power plants
- Residual material: app. 0.5 - 2 % → disposal
- Metals: 50 % recycling rate → secondary raw material
- Water: up to 267 m³/day

Key figures

• Capacity	1,000 tons/day 356,000 tons/year	
• Power generation	6.00 MW gross 4.50 MW net	
• Staff demand	70	
• Construction period	20-24 month	
• CAPEX	Pre-treatment:	approx. 4 Million USD
	MYT® process:	approx. 44 Million USD
	Biological Drying:	approx. 9 Million USD
Total:		approx. 57 Million USD
• OPEX	15.4 USD/ton 4.7 Million USD/year (without refinancing)	
• Revenues		
Tipping fee:	(22 USD/ton*)	7.80 Million USD/year
FIT:	(0.1005 USD/kWh*)	4.20 Million USD/year

RDF value: (14 USD/ton*) 2.50 Million USD/year
(based on information from international cement producers)
Total Revenues (approx.) 14.5 Million USD/year

*assumed figures

A process flow diagram with a mass balance for the proposed MYT® process is included in the appendices in Chapter 7.

5.2.2.5. COST ESTIMATION FOR MECHANICAL-BIOLOGICAL TREATMENT WITH MYT® PROCESS

Table 12: Cost estimation of MYT® process (example Laguna)

1	**CAPEX** MYT® technology	USD	**57,000,000**
2	**OPEX** (without refinancing)	USD/year	**4,700,000**
3	**Revenues** (through FIT)	USD/year	**14,500,000**

5.2.2.6. OUTLOOK ON A COMBINED LEACHATE AND PROCESS WATER TREATMENT

A combined aerobic treatment of landfill leachate together with surplus water from the MYT® process would certainly show benefits:

Investment costs: An effluent treatment plant with a capacity of ~450 m³/day for the MYT® process alone already requires an investment of ~3.9 Million USD. If the capacity of this treatment plant were doubled by adding the landfill leachate to the MYT® effluent, the respective investment costs, however, would not double but only increase by about 50 %.

Operating costs: The operating costs of leachate treatment after the upgrade are expected to lie at about 4.00 USD per m³. A doubling of the plant's treatment volume by adding the MYT® effluent is expected to result in a cost reduction of about 20 % because of reduced personnel requirements, larger procurement volumes and a proportionally reduced power uptake. Thus the expected treatment costs per m³ for a combined treatment plant lie at about 3.20 USD.

5.2.2.7. OUTLOOK ON COMBINED LANDFILL GAS AND BIOGAS UTLIIZATION

Existing landfill sites that have no landfill gas capturing systems could also benefit from the MYT® process. Landfill cells which have so far not been equipped with a gas capturing system could still be equipped with one in order to be able to extract the landfill gas in future and be able to at least feed it to a flare. Yet such a retrofit may cause high costs.

If the gas could be captured and be lead to a site with a MYT® plant the landfill gas from the connected cells could be energetically utilized together with the biogas from the anaerobic stage. However, as there is no alternative site identified, this aspect would have to be examined in a separate study.

5.3. ENERGETC UTILIZATION OF THE GENERATED FUELS

For the utilization of the HCF and / or the RDF produced in an MYT® plant different options exist:

HCF →	Thermal utilization (power plant)
HCF + RDF →	Thermal utilization (power plant)
	Energetic utilization (cogeneration plant "green utilization")
RDF →	Energetic utilization (cogeneration plant "green utilization", cement works)

Decisive for the economic utilization of the HCF / RDF are for example their calorific value (the higher, the better), a low chloride content or the proximity of the recovery facility. An additional payment for the energy provided by these waste-derived fuels would also support the utilization.

In case these waste-derived fuels cannot be used by e.g. cement plants, industrial power plants, a "green utilization" of the energy should be considered. The meaning of the term “green utilization” will be explained in the following paragraphs.

First of all, a "green utilization" should fulfill objectives in order to make sense:

- The system should be much simpler and less expensive than previously built incinerators
- The plant should be significantly lower in emissions than previously built incinerators
- The plant should in particular consider the aspect of the recovery of raw materials.

A "green utilization" system consists of the three components:

Module 1: Fuel preparation

The MYT® process produces several waste-derived fuels with different properties. In order to achieve RDF with a high calorific value and a minimum amount of impurities, the waste-derived fuels need to be treated.

Thus additional process steps are integrated to remove pollutants and non-combustible components. Remaining recyclables such as metals and plastics and non-combustible material should be removed as far as possible before combustion. As a result the fuel quantity is maximized.

In the fuel preparation, the RDF can be crushed with the aim to produce as homogeneous a mixture as possible for this considerably improves the combustion process:

Conventional incinerators receive different grain sizes as fuel, this causes unfavorable conditions in the combustion chamber. This can be prevented by the highest possible homogeneity of the fuel. The combustion process can thus be optimally designed and optimal results in terms of burnout and flue gas cleaning can be achieved.

An especially designed process management within the MYT® process aims additionally at minimizing the concentrations of sulfur, chlorine and metals, for example, at the entrance of the combustion chamber.

Module 2: Ashing process

The choice of the right ashing process is very important for the recovery of valuable materials (rare raw materials) from the substitute fuels. The process should be simple and robust and had best be modular expandable. Additionally, the chosen ashing process should allow the use of a variety of feedstock. The ashing process should achieve uniform fuel guidance and minimize turbulence in the combustion chamber. The ventilation air also used for cooling purposes can be minimized and should be blown in laterally due to fuel preparation to reduce the amount of fly-ash escaping with the combustion air. All in all, this means that an optimal management of the air in the combustion chamber is of high importance. This air management is decidedly affected by the preceding stages for the fuel preparation as described in Module 1. This all reduces the amount of ash produced significantly.

Another very important and positive effect of optimizing the ashing process is that the flue gas is significantly cleared of pollutants. Thus the exhaust air treatment (as state-of-the-art) achieves an air quality which is significantly better than international standards require.

Module 3: Raw material recovery

As a result of the optimal ashing process, the concentration of substances which are worth-while recovering (phosphates or rare earths, for example) is significantly increased. For example the concentration of phosphorus and other valuable substances in the ash is about three times higher than in the original substitute fuel. This renders processes for the recovery raw materials more economical.

In the end, there remains a very small residual stream from the MYT® process which mainly consists of inert materials (sand, broken glass, etc.) and which complies with the European landfill guidelines. This leftover can then be safely deposited on a landfill site.

5.4. COST COMPILATION

The table below displays the amount of money involved for the investment costs (CAPEX) - as explained in the technical comments, the operational costs (OPEX) and the revenues.

Table 13: Cost compilation for the proposed implementation concepts (Reference: WEHRLE)

		Mechanical Treatment	Mechanical biological treatment (Composting)	Mechanical biological treatment (Biogas and biodrying)
Waste amount	t/d	200	200	1.000
CAPEX	USD	1.000.000	2.000.000	57.000.000
OPEX	USD	270.000	480.000	4.700.000
REVENUES	USD	110.000	180.000	14.500.000

6. CONCLUSION

The analysis undertaken in this report shows various waste facilities in the Philippines and their potential for improvement. For future new waste disposal techniques, four different solutions have been identified, taking into account the technical and financial possibilities of the respective waste management authorities. All options assume that recyclable substances are already segregated at household level. Those recyclables & reusable substances that are not segregated at the point of origin, should be separated and converted into usable products at the waste treatment plant. This could be for example compost for agricultural use, recyclable materials or substances with an optimal condition for energy recovery in industrial processes.

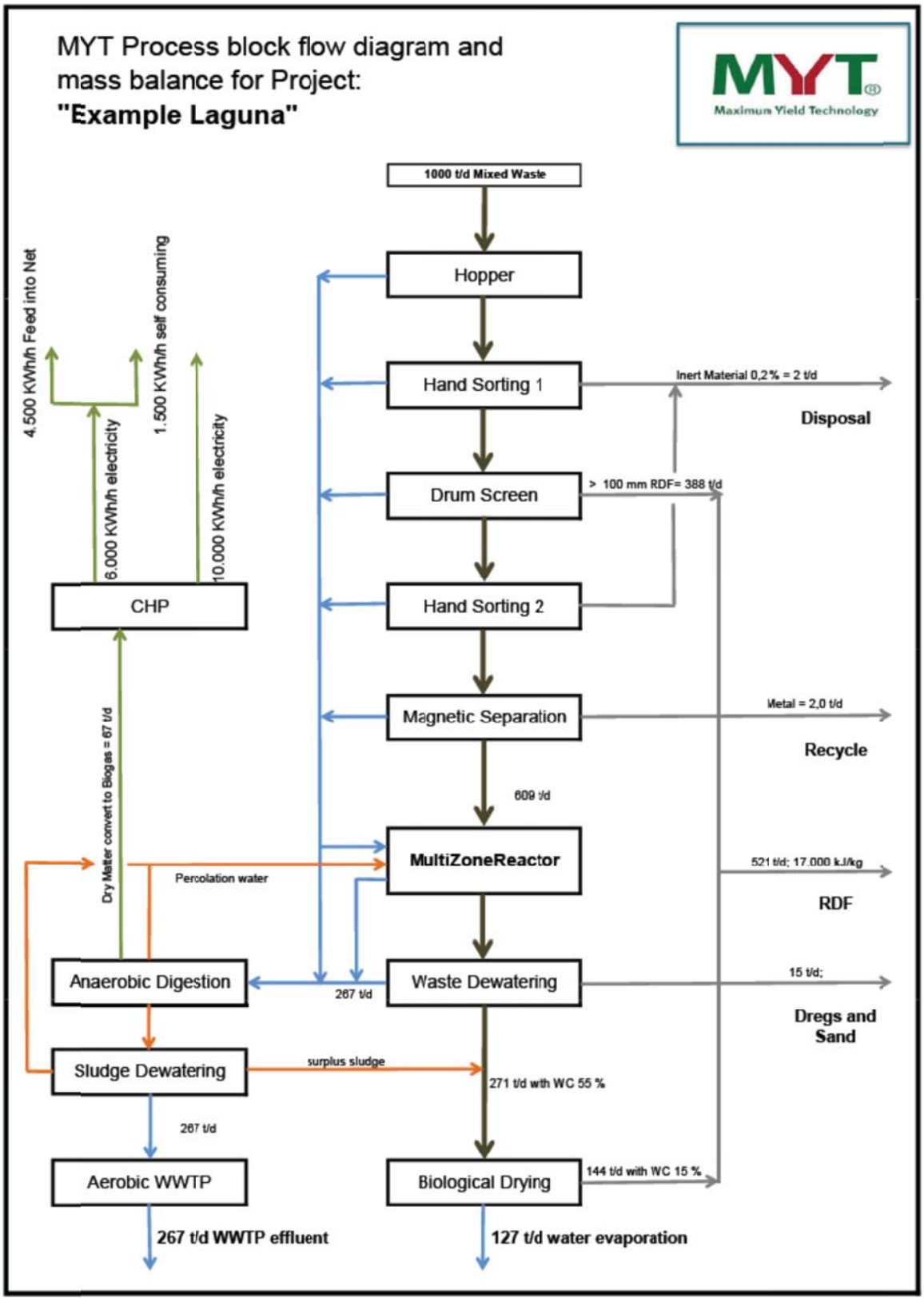
Site visits revealed that in smaller communities only low-tech solutions can be realized. This means that the municipality should provide a solution for the treatment of the garbage remaining after the segregation of recyclables within the individual households. Such a solution could be simple mechanical waste treatment devices such as screens, for example, which could be built locally. Thus, the organic compounds of the waste could be separated from ingredients with a higher calorific value. The organics can then be composted and the compost used for agricultural purposes in compliance with the required compost qualities.

When it comes to larger waste quantities (>50 tons/day), such simple technologies are no longer applicable because of their high personnel requirements. For these waste sites, another concept was developed. It includes – after a first waste segregation on household-level – an upfront separation of metals and of high-calorific plastics or recyclable materials, followed by a biological treatment such as box composting of the remaining waste. Thus the biologically treated organic ingredients can be converted to a high quality compost, perhaps with the use of further mechanical separation techniques.

The investment costs, but also the sustainability of each concept increases the higher the technical level becomes. Thus it might make sense to treat waste from different communities jointly. Therefore a model plant was developed: for this model plant, the waste volumes as well as the waste concentrations of various municipalities were examined. In a second step different municipalities who could sensibly merge their waste were identified (“clustering”). This exemplary clustering was done paying attention to the transport required to get the waste from *a* to *b*. Then a model plant was developed for such a cluster and a process description as well as its investment and operating costs were presented. The process chain comprised the MYT Technology which converts components of the waste into usable products. Here, the objective of a high fuel quality in the residual products is of particular interest.

The visits and discussions with local authorities have shown how difficult it is especially for smaller communities to implement sustainable waste management technologies. Thus the need for the co-development of waste treatment concepts for groups of neighboring communities working together (“cluster”) is the key to the implementation of a modern, technically efficient = sustainable and environmentally friendly treatment technology.

7. APPENDICES


MYT Process block flow diagram and mass balance for Project:
"Example Laguna"
MYT
Maximum Yield Technology
1000 t/d Mixed Waste
Hopper
Hand Sorting 1
Inert Material 0,2 % = 2 t/d
Disposal
Drum Screen
> 100 mm RDF= 388 t/d
Hand Sorting 2
Magnetic Separation
Metal = 2,0 t/d
Recycle
609 t/d
MultiZoneReactor
521 t/d; 17.000 kJ/kg
RDF
Waste Dewatering
15 t/d;
Dregs and Sand
267 t/d
271 t/d with WC 55 %
Biological Drying
144 t/d with WC 15 %
127 t/d water evaporation
CHP
4.500 KWh/h Feed into Net
1.500 KWh/h self consuming
6.000 KWh/h electricity
10.000 KWh/h electricity
Dry Matter convert to Biogas = 67 t/d
Percolation water
Anaerobic Digestion
Sludge Dewatering
surplus sludge
267 t/d
Aerobic WWTP
267 t/d WWTP effluent