Integrated Solid Waste Management

A Course Review

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- Course Overview
- Lecture Series
- Exercises
- Excursions
- Group Exercise

Course Overview

2 Logical course build-up

Historical logic or logic of the waste hierarchy

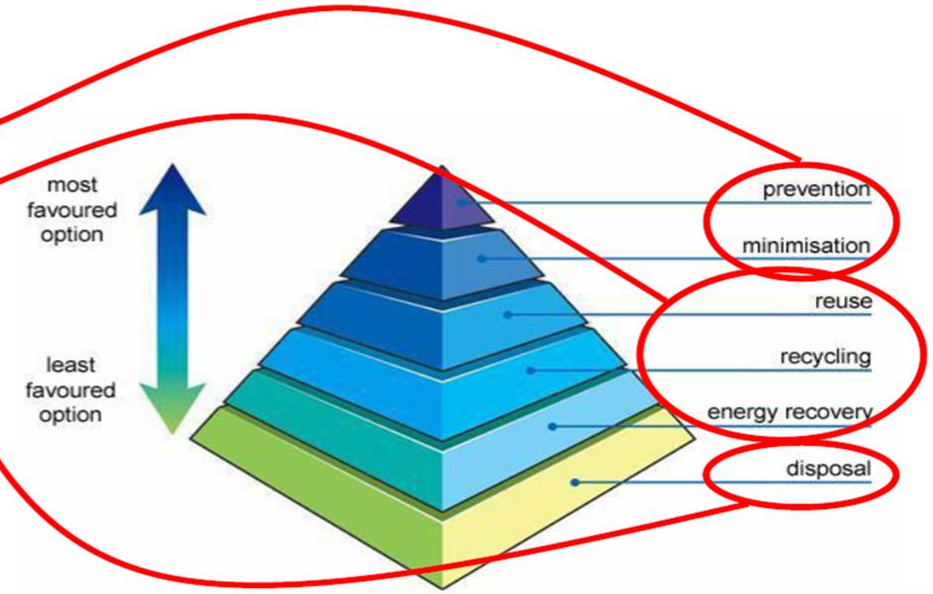
Present

3 - Generation and prevention
(week 3)

2 - Re-use and recycling
(week 2)

1 - Treatment and disposal
(week 1)

Past



Course Overview

Module11 - Short course on Solid Waste Management 2016

	1 Treatment & disposal			2 Re-use & recycling			3 Generation & prevention	
	Group 1	Group 2		Group 1	Group 2	2	Group 1	Group 2
Mon	June 27		Mon	July 4		Mon	July 11	
1	Registration		1	Exc. Recycling Center	Groupwork	1	Abarca - Planning	Abarca - Planning
2	Siebel - Introduction Course & Groupwork		2	TUB(Rotter) - Waste to energy & incineration		2		
3	Siebel - Stakeholders	TUB(Larsen) - Collection	3	TUB(Rotter) - WM and climate change		3	Abarca - Planning	Abarca - Planning
4	TUB(Larsen) - Collection	Siebel - Stakeholders	4	Groupwork	Groupwork	4		
Tue	June 28		Tue	July 5		Tue	July 12	
1	Siebel - Getting the group work started		1	TUB(Larsen) - Biogas		1	Siebel - Waste Prevention	
2			2	TUB(Larsen) - Waste to energy Calculations		2	Velkushanova - Financial aspects 1	
3	Siebel - Presentations by participants		3	Presentations by participants		3		
4	Groupwork	Groupwork	4	TUB(Larsen) - Tutoring calculations	TUB(Rotter) - Tutoring calculations	4		
Wed	June 29		Wed	July 6		Wed	July 13	
1	TUB(Larsen) - Intro calculations waste generation		1	Excursion Antwerp Igean & Hooge Maey		1	Velkushanova - Financial aspects 2	
2			2			2		
3	Groupwork		3			3	TUB(Fritze) - Groupwork Q&A	
4			4			4	Groupwork	Groupwork
Thu	June 30		Thu	July 7		Thu	July 14	
1	TUB(Larsen) - Landfill technology		1	Groupwork	Exc. Recycling Center	1	TUB (Fritze) - Groupwork Q&A	
2			2	TUB (Fritze) - Groupwork Q&A		2	Groupwork	Groupwork
3	TUB(Heiming) - Landfill Calculations		3	Rotter - Groupwork presentations		3	Groupwork	Groupwork
4			4	Groupwork		4	Groupwork	
Fri	July 1		Fri	July 8		Fri	July 15	
1	TUB(Larsen) - MBT and composting		1	TUB(Rotter) - Introduction to Economics of Waste Management and Recycling		1	Groupwork Final presentations Rotter & Siebel	
2			2			2		
3	TUB(Heiming) - Calculations MBT and composting		3	TUB(Rotter) - Material Recycling		3	How to continue? Building up a network	
4	Groupwork	Groupwork	4			4		

Lecture Series

Origins of Waste

- Generation
- Characterization
- Collection

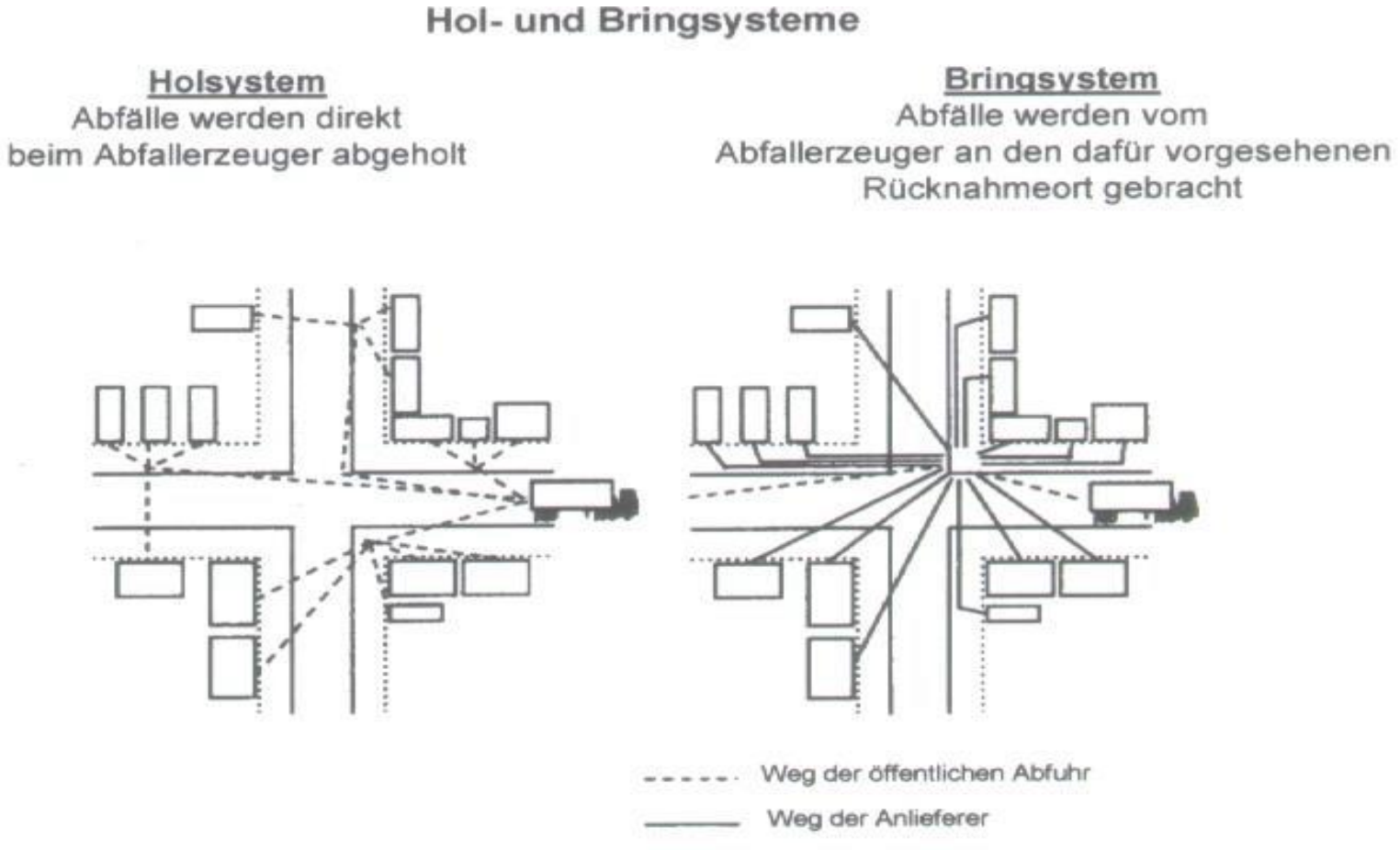
Treatment and Disposal

- Sanitary Landfill
- MBT
- Composting
- Incineration

Reuse, Reduce, Recycle

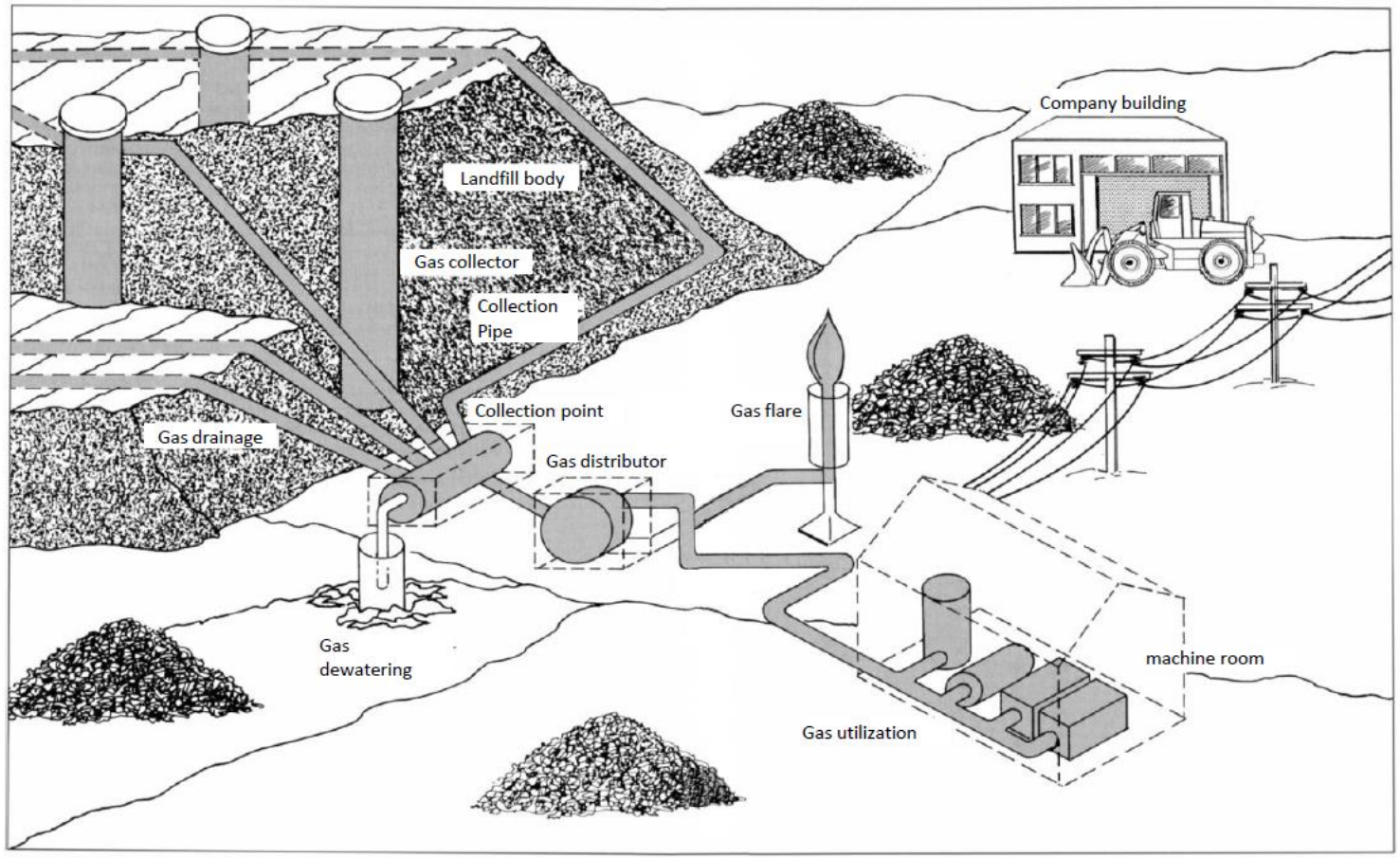
Financing

Examples of Lectures



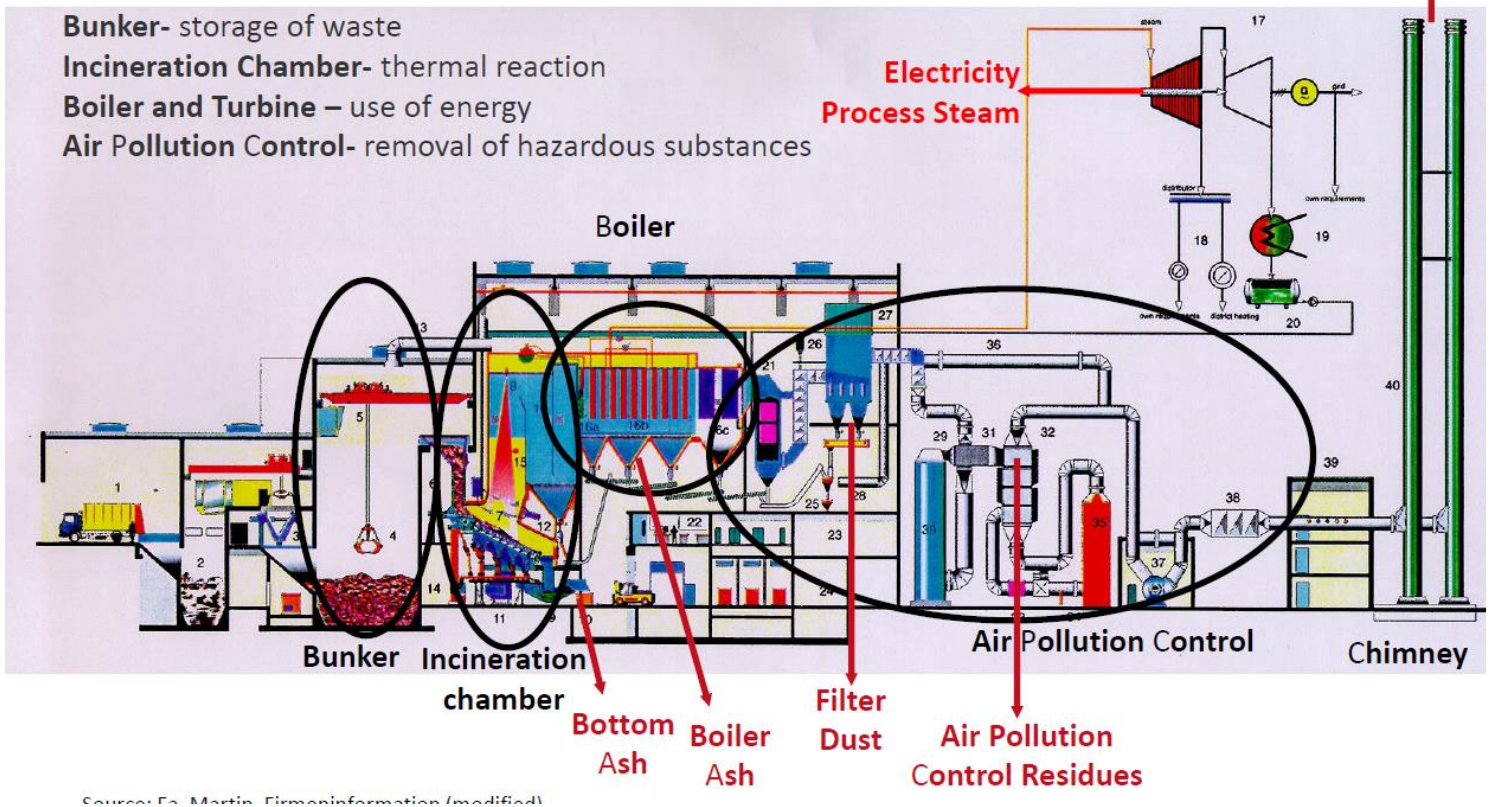
Examples of Lectures

Design of a Landfill Gas Management System



Examples of Lectures

Layout of a Waste Incineration (MSWI) Plant

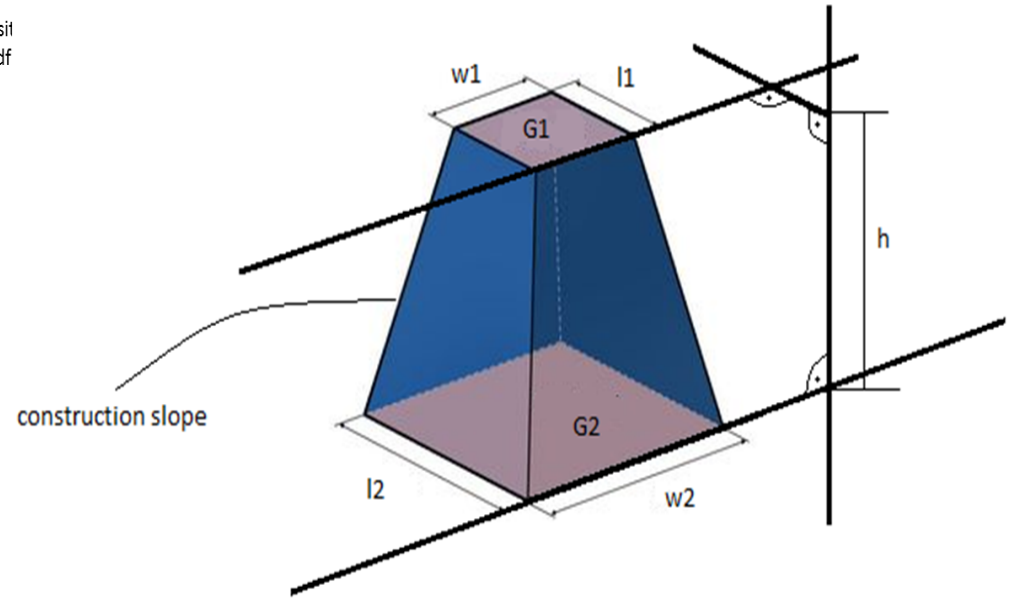


Source: Fa. Martin, Firmeninformation (modified)

Exercises

Aim of step b) modelling of the landfill geometry

In order to design the leachate collection system in step c), we need to caculate the base area of the landfill body G_2 at first. Therefore we have to choose an appropriate landfill geometry and fit it's parameters to the total volume of waste to be landfilled
during the operational time and to the site conditions. In our example, the landfil width w_1 shall be given du to the sit
will thus fit the geometry of the landfill body to the total volume of waste to be landfilled by variation of the free landf



1. Choose an appropriate landfill geometry

The landfill body will be approximated as a straight truncated pyramid with
rectangular base G_2 (see figure). It's volume is given by $V\_calc = h/3 \cdot (G\_1 + G\_2 + \sqrt{(G\_1 \cdot G\_2)})$,
where $G\_1 = l\_1 \cdot w\_1$; $G\_2 = l\_2 \cdot w\_2$; $l\_2 = l\_1 + 2 \cdot h \cdot slope$; $w\_2 = w\_1 + 2 \cdot h \cdot slope$.

2. Collect Given data from previous calculations and site conditions:

$V\_waste = total\ volume\ of\ waste\ to\ be\ landfilled\ during\ operational\ time$
$h = 25m$
$w\_1 = 300\,m$
construction slope: $w/h = 3m/1m$

3. Calculate the base area G_2

Since the formula $V\_calc = h/3 \cdot (G\_1 + G\_2 + \sqrt{(G\_1 \cdot G\_2)})$ cannot be solved analytically
for G_2, we will calculate G_2 iteratively using Excel's "Goal Seek" function. For doing so, please follow these steps:

1. Type the formulas given above, or, if applicable, the given data into the respective green cells B17-B22
2. Type V_waste - V_calc into cell # B24
3. Place a link to cell # B13 into the orange cell # B23
4. Click register "Data" -> "What-if-analysis" -> "Goal Seek" function. A dialog box appears. Please link the text field input "Set Cell" to cell # B24 and type "0" into the text field input "To value". Link the text field input "By changing cell" to the yellow cell # B16. Then click "ok".

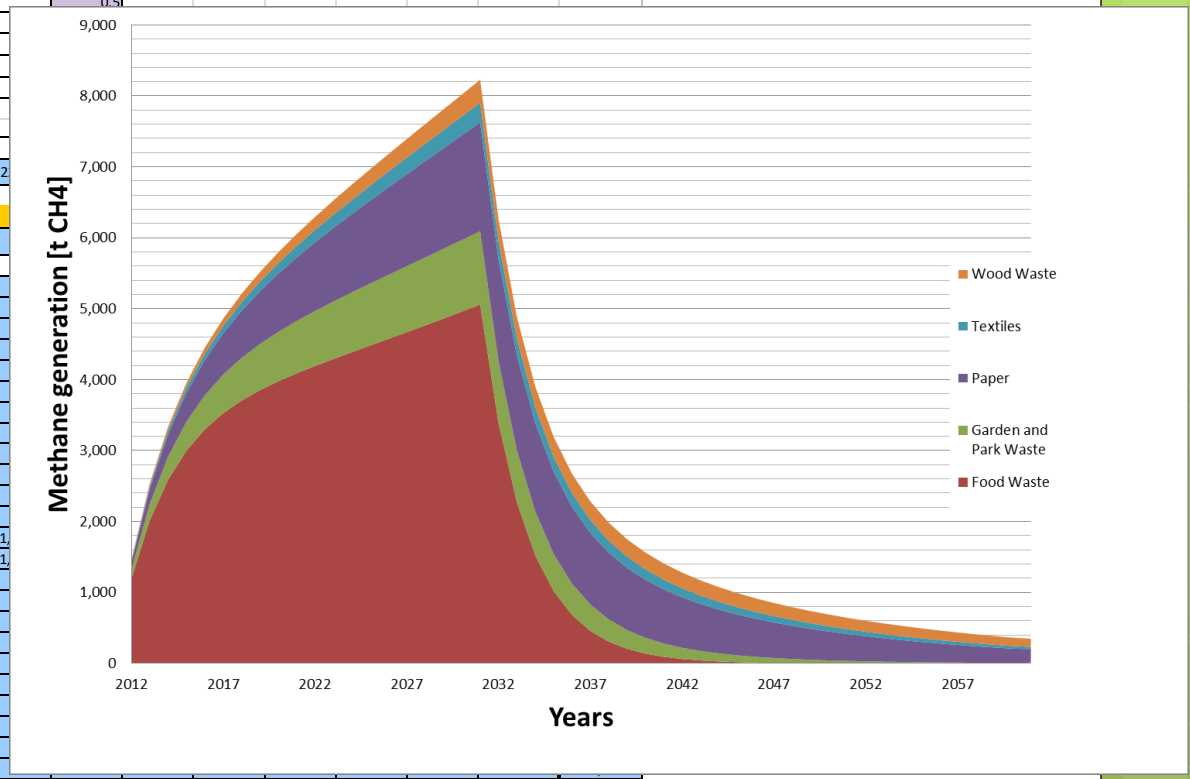
Excel will now automatically vary the free l_1 value in cell # B16 and calculate V_calc out of the depending variables until $V\_waste - V\_calc$ in cell # B24 equals zero and thus V_calc= V_waste is true. Now the geometry has been fitted to the total waste volume to be landfilled and the G2 value in cell # B21 is the respective base area of the landfill body.

Exercises

Waste characterisation				Application	A				Parameters			
Waste stream	waste composition	DOCj (wet waste)	Decay rate k_j	Tropical Climate (MAT>20°C) wet (MAP > 1000mm)					f	fraction of methane captured and flared/combusted/used	0.00	no gas capture exists
Food Waste	60%	15%	0.400						ϕ	"model correction factor"	0.75	
Garden and Park Waste	10%	20%	0.170	given data					F	fraction of CH4 in LFG	0.5	
Wood Waste	3%	43%	0.035	calculation field					DOC_f	fraction of DOC dissimilated		
Paper	10%	40%	0.070	methodological tool					MCF	methane correction factor		
Textiles	3%	24%	0.070						OX	Oxidation factor		
Other	14%	0%	0.000							ϕ x (1-OX) x 16/12 x F x DOCf x MCF		
total	100%			Global Warming Potential (GWP)						1st Order decay		
				28								

Year	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	
amount landfilled [$t_{wet\ waste}$]	178,360	181,927	185,566	189,277	193,063	196,924	200,862	204,880	208,977	213,157	217,420	221,768	2

Food Waste																					
$W_j*DOC_j*(1-e^{-kj})$ [t]	5,292	5,398	5,506	5,616	5,728	5,843	5,960	6,079	6,201	6,325	6,451	6,580									
year of prognosis																					
2012	1,191																				
2013	798	1,215																			
2014	535	814	1,239																		
2015	359	546	830	1,264																	
2016	240	366	557	847	1,289																
2017	161	245	373	568	864	1,315															
2018	108	164	250	381	579	881	1,341														
2019	72	110	168	255	388	591	899	1,368													
2020	49	74	112	171	260	396	603	917	1,395												
2021	33	50	75	115	174	265	404	615	935	1,423											
2022	22	33	50	77	117	178	271	412	627	954	1,451										
2023	15	22	34	52	78	119	181	276	420	639	973	1,481									
2024	10	15	23	35	53	80	122	185	282	429	652	992	1,								
2025	7	10	15	23	35	54	82	124	189	287	437	665	1,								
2026	4	7	10	16	24	36	55	83	127	193	293	446									
2027	3	4	7	10	16	24	37	56	85	129	196	299									
2028	2	3	5	7	11	16	25	37	57	87	132	200									
2029	1	2	3	5	7	11	16	25	38	58	88	134									
2030	1	1	2	3	5	7	11	17	26	39	59	90									
2031	1	1	1	2	3	5	7	11	17	26	40	60									
2032	0	1	1	1	2	3	5	8	11	17	27	40									
2033	0	0	1	1	1	2	3	5	8	12	18	27									
2034	0	0	0	1	1	1	2	3	5	8	12	18									
2035	0	0	0	0	1	1	1	2	3	5	8	12									
2036	0	0	0	0	0	1	1	2	2	4	5	8	12	19	29	44	67	101	154	235	685
2037	0	0	0	0	0	0	1	1	2	2	4	5	8	13	19	29	45	68	103	157	459
2038	0	0	0	0	0	0	0	1	1	2	2	4	6	8	13	20	30	46	69	105	308
2039	0	0	0	0	0	0	0	0	1	1	2	2	4	6	9	13	20	31	46	71	206
2040	0	0	0	0	0	0	0	0	0	1	1	2	3	4	6	9	13	20	31	47	138



Excursions


North Sea
Haarlem
Amsterdam
Zwolle
The Hague
Utrecht
Enschede
Rotterdam
Rhine
Tilburg
Middelburg
Eindhoven
Terneuzen
Brugge
Antwerp
Gent
Poperinge
Brussels
Maastricht
Cologne

Excursions

Excursions

Group Exercise

Solid Waste Management

DESCRIPTIONS OF THE REGIONS

Group work 2016

Small Island state Vanaestia	Coastal region Atlantua		Province of a mountain state Montagia	Flat land area Deseavantiga
9 Islands, 260-800 km^2 , 35-1250 km apart, nearest islands 1500 km, moderately mountainous, volcanic origin; monsoon winds	126 km coastal land 15-75 km wide, beach/rocks, city A: 65,000, B 15,000 inh, 2 oblong, fertile islands parallel to coast (±8km), 30,000 inh.	Geography	3,500 km^2 , 10% arible, mountains 750 – 3500 m high, one large river crosses country, one border crossing	5,000 km^2 ondulating, partly fertile land, crossed by 3 major rivers, 15-150 masl, 4 seasons, temps -5-25, humidity 55%,
avg precipitation: 750 mm/a; humidity 65%; temp.21-28°C; floodings annually recurring; hurricane prone region in summer period	predominantly offshore wind, precipation 450 mm/a (3 months), temp 25±4°C; avg. humidity 25%, sunshine 3800 hrs/a,	Meteorology	Mountain winds, precipitation @ 600 mm/a (with up to 300 mm/24 hrs), sunshine 1900 hrs/a;	Avg precipitation 750 mm/a, humidity 55%, sunshine 2500 hrs/a, strong southens winds not uncommon
avg. 75/km^2, 55% along 15 km coastal zone; BANP$/C[1]) 1550; Ed: 5%Uny, 25%Sec,65% Prim	Total population: 280,000; BANP$/C[1]) 9550; Ed: 15%Uny, 45%Sec, 30%Prim	Population	650,000 inh, 54% in 2 cities, BANP$/C[1]) 1500, Ed: 7.5%Uny, 45%Sec, 35%Prim	Population 1.5 million, 35% in 2 cities 100 km apart, BANP$/C[1]) 6500, Ed: 12.5%Uny, 55%Sec, 30%Prim
small trades: fishing, agriculture, cattle, tourism, wood, leather, horticulture	Tourism income , 1.2 million tourist nights in 3 months; wood industry & agriculture #2 & 3, fishing #4	Economy	Forestry, energy, tourism (5.5 million tourist nights/yr),	Agriculture, cattle breeding, meat industry, tourism, forestry, leather industry, transportation,

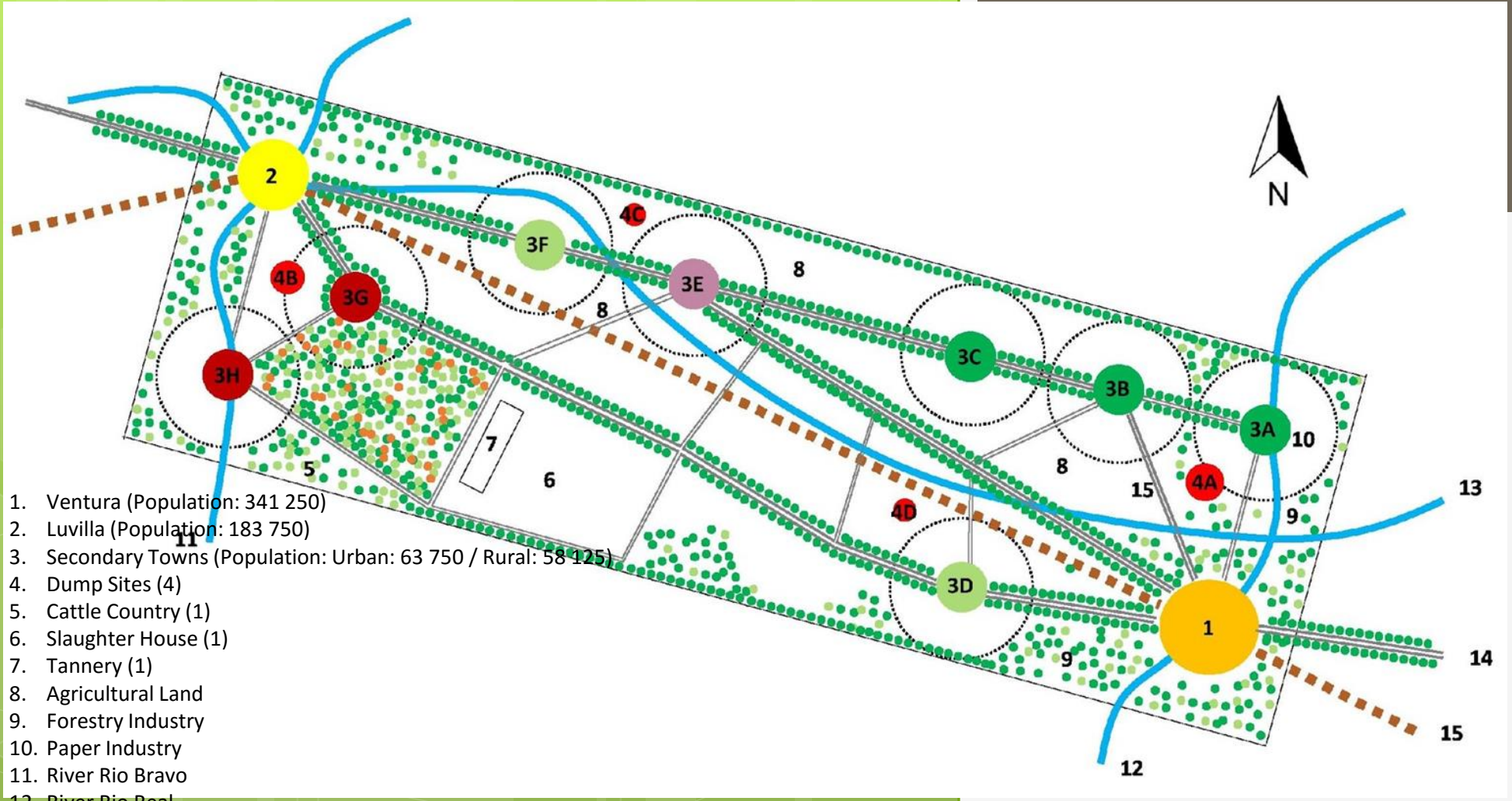
[1]) Bruto Annual National Product in US$/Cap (BANP$/C)

DESEAVANTIGA INTEGRATED SOLID WASTE MANAGEMENT PLAN 2016 - 2031

Fernando Bião Lima
Vivian Castro-Wooldridge
Neelam Pradhananga
Lu Shen

1. The Context

DESEAVANTIGA REGIONAL MAP



1. Ventura (Population: 341 250)
2. Luvilla (Population: 183 750)
3. Secondary Towns (Population: Urban: 63 750 / Rural: 58 125)
4. Dump Sites (4)
5. Cattle Country (1)
6. Slaughter House (1)
7. Tannery (1)
8. Agricultural Land
9. Forestry Industry
10. Paper Industry
11. River Rio Bravo
12. River Rio Real
13. River d'Oro
14. Highways
15. Railway
16. Roads

Geographic Data

Area of 5,000 $m^{2,}$ undulating, partly fertile, 3 major rivers, 15-150 mean ASL, 4 seasons, Temps -5 to 25 degrees C, humidity 55%

Climatic Data

Average precipitation 750 mm/year, humidity 55%, sunshine 2500 hrs/annum, strong southern winds not uncommon

Demographic Data

Pop. 1.5 million, 35% in 2 cities 100 km apart, BANP$/C 6500, Education: 12.5% university, 55% secondary and 33% primary

Economic Data

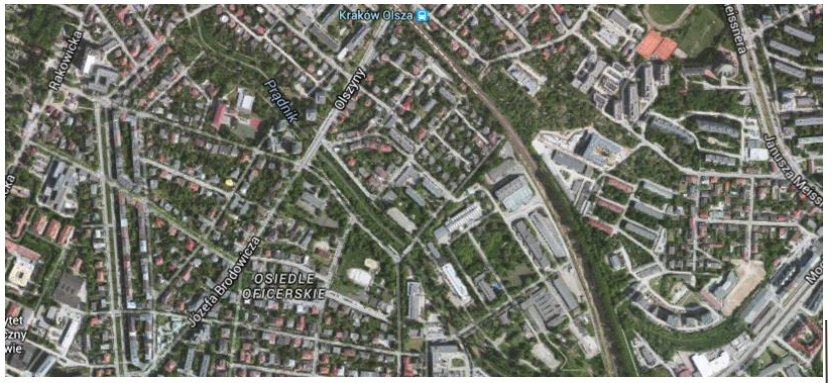
Agriculture, cattle breeding, meat industry, tourism, forestry, leather industry, transportation

CURRENT WASTE MANAGEMENT SYSTEMS IN THE REGION

VENTURA

- Local government provides collection services
- Service is unreliable
- Collection coverage - 70%
- Door-to-door collection - 2x/ week
- Composting is insignificant
- Open dumpsites used
- **Large dump site near Ventura and Luvila**
- Informal waste workers recover some resources from HHs
- Some illegal dumping in rivers

LUVILA

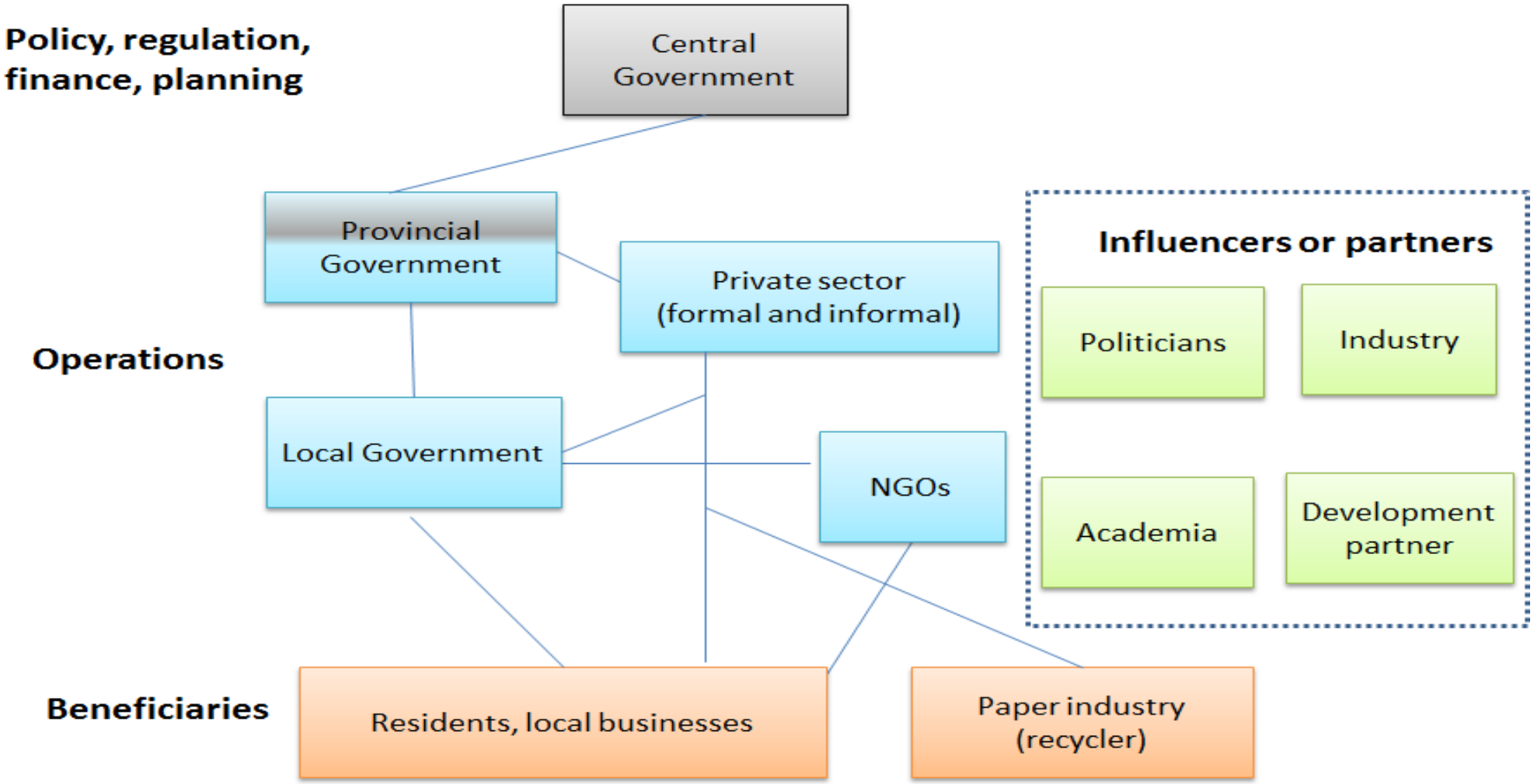


8 SECONDARY TOWNS

- Local government provides collection services
- Service is unreliable
- Collection coverage - 70% (urban)
- **Collection coverage - 30% (rural)**
- Door-to-door collection- 2x week (urban)
- **Collection (rural) - common collection points**
- Composting - Low (urban), **High (rural)**
- Informal waste workers recover some resources from HHs
- **2 medium sized dumpsites nearby**
- Open dumpsites used
- Some illegal dumping in rivers

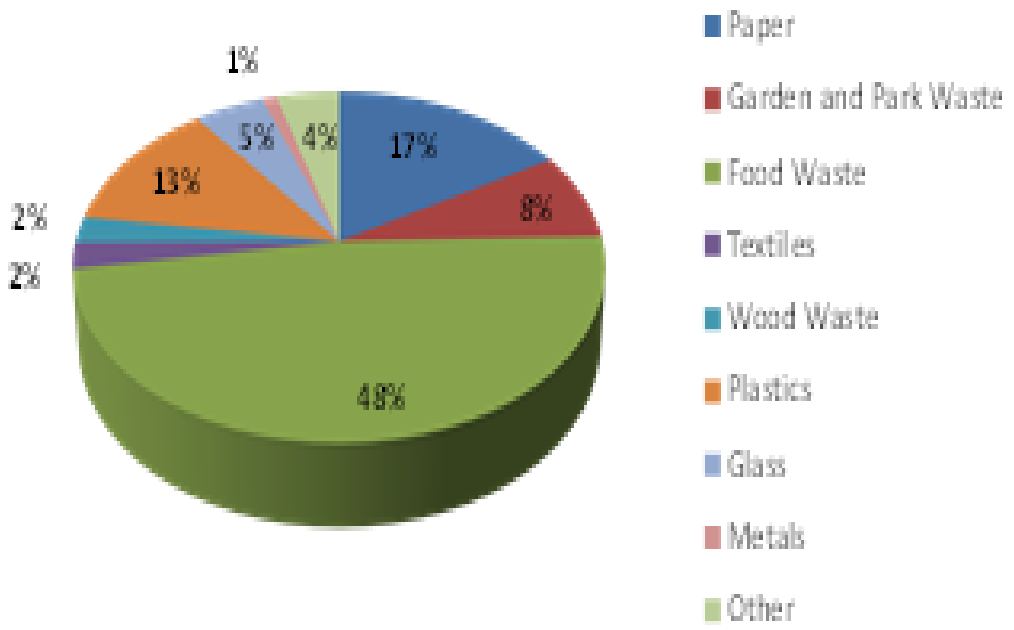
Blue text = key differences between large & small towns

STAKEHOLDER ANALYSIS

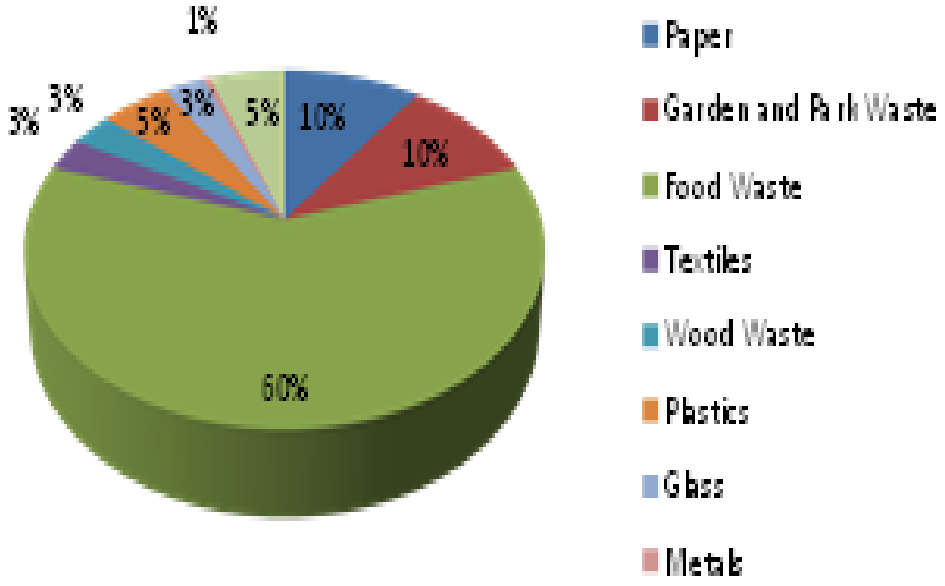


WASTE GENERATION

At HH level

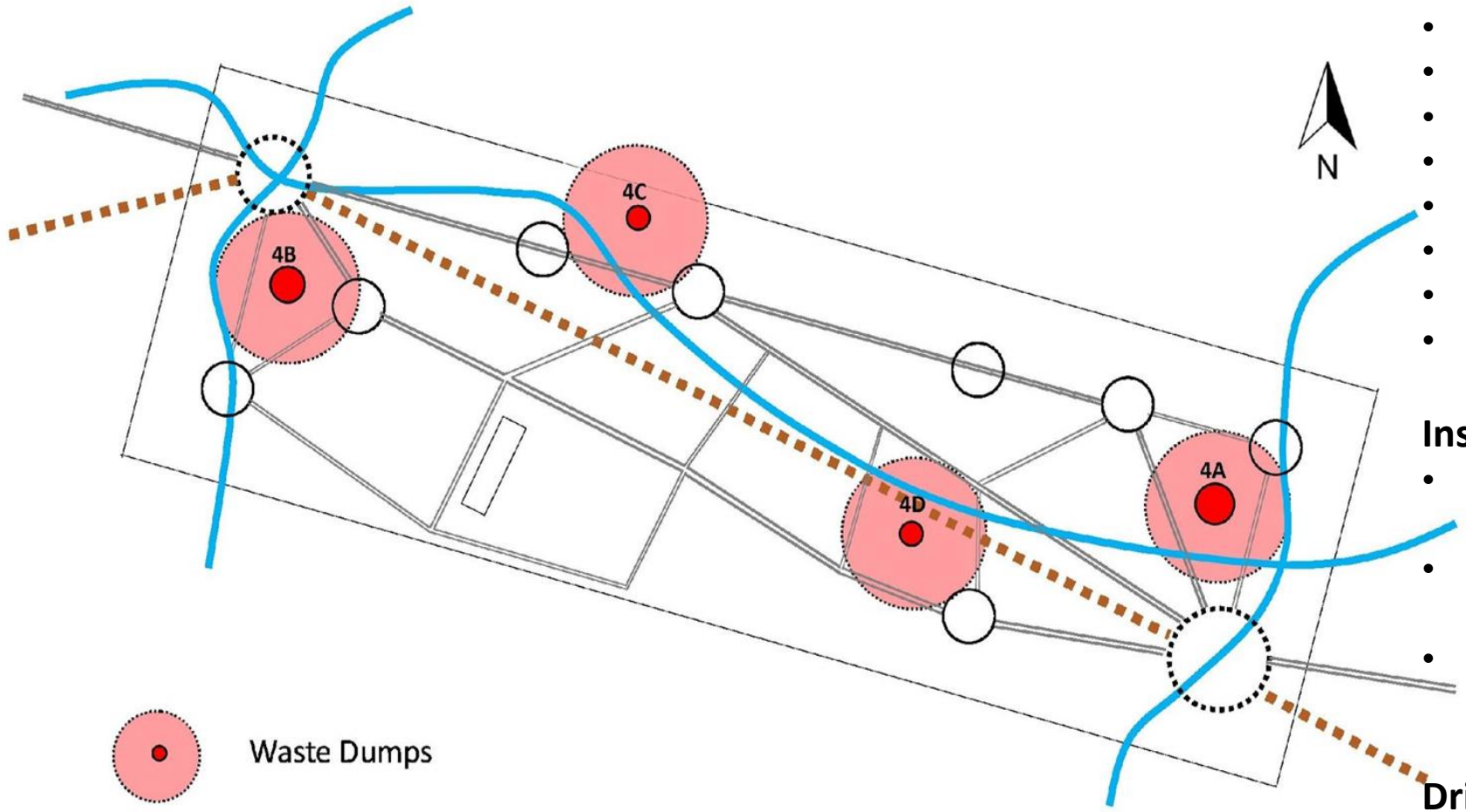


From HHs after informal collection



Informal waste pickers:
collect 20% of total mass
recycle 47% of recyclable materials

MAIN ISSUES IN WASTE MANAGEMENT



Key Issues

- 4 dumpsites
- Groundwater pollution
- Widespread littering
- High use of plastic bags
- Informal waste workers
- Unreliable collection
- Inadequate tariffs
- Tannery & slaughterhouse waste

Institutional Framework

- Lack of clarity on stakeholders roles/ responsibilities
- Rudimentary Act and regulations exist; they do not cover hazardous waste
- Regulation is weak with little to no enforcement

Drivers for Change

- Tourism industry
- Demands by the general public

2. The Future

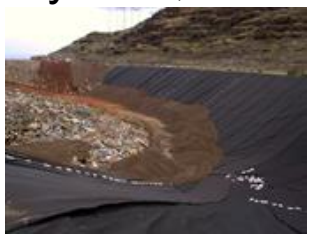
A GREEN DESEAVANTIGA: A VISION FOR SWM

INSTITUTIONAL	POLICY	REGULATORY	FINANCE	SOCIO-CULTURAL
Create a strong and robust institutional framework to guide regional system	Improve policies and industrial waste management	Improve the regulatory mechanism to ensure laws and policies are complied with	Ensure tariffs are affordable and set at cost recovery levels	Ensure citizens are aware of their important role and options to reduce waste
Build capacity of the new regional utility; absorb current municipal staff		Enact and enforce laws on littering, use of plastic bags, open burning		Eliminate widespread littering and open burning
Operationalize data management system for M&E, decision-making				Acknowledge and support informal waste workers

SUSTAINABILITY CRITERIA ANALYSIS

Scenario 1 - Basecase

dumpsite remediation, improved collection system, landfill, transfer station



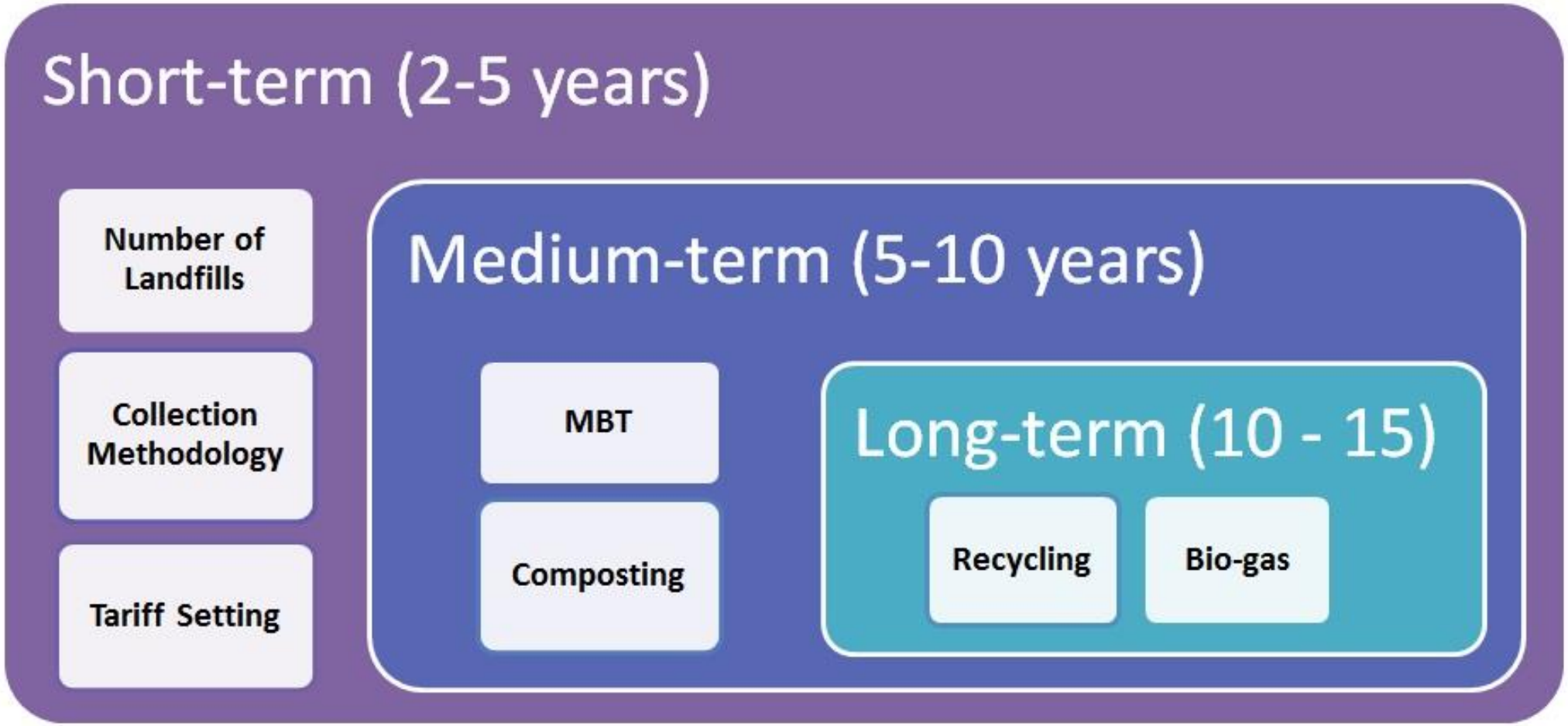
Scenario 2 - Basecase + MBT

Scenario 3 - Basecase + MBT + Biogas plant

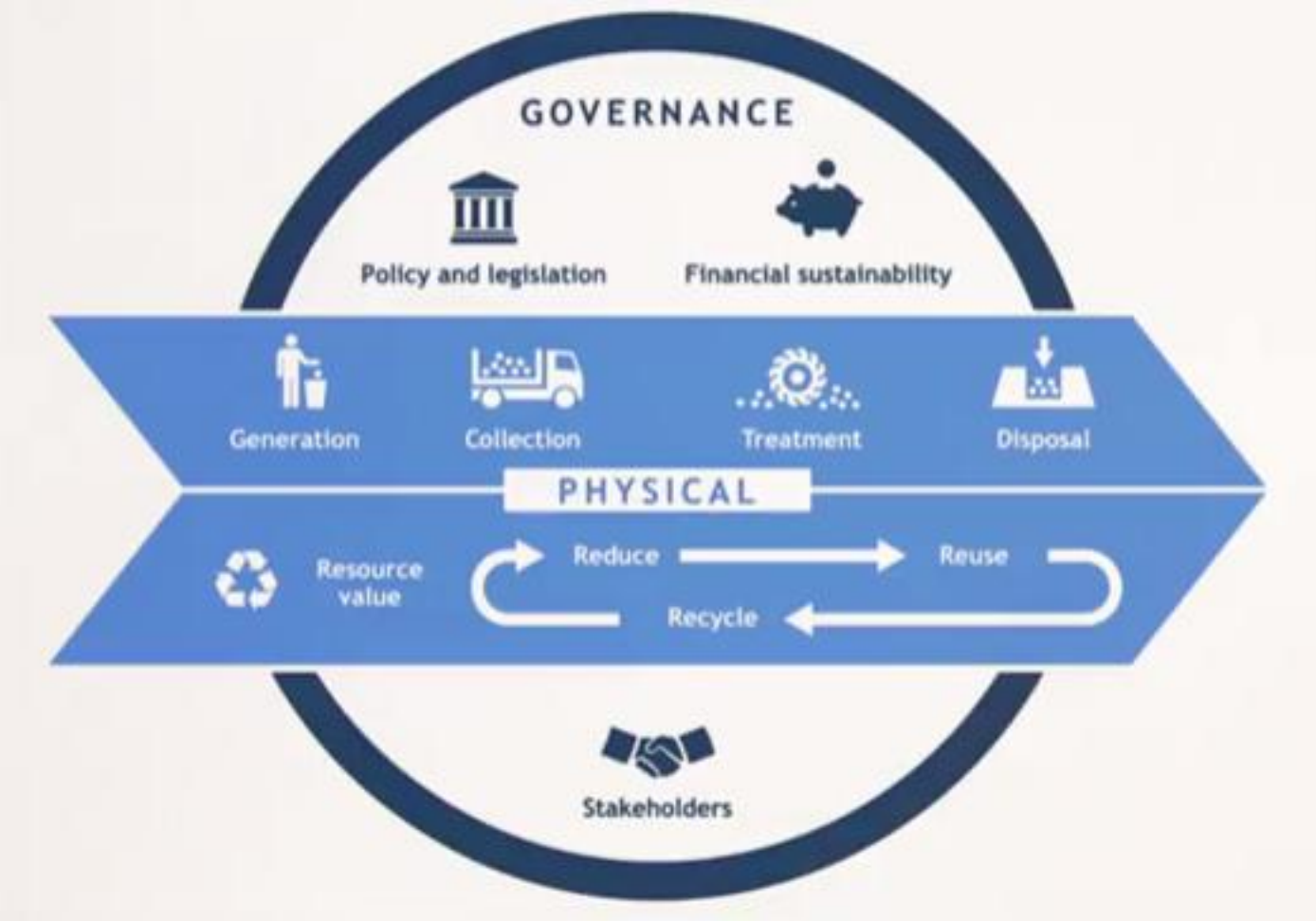
Scorecard

	Scenario 1	Scenario 2	Scenario 3
Financial			
CAPEX	3	2	1
OPEX	3	2	1
Environmental			
Greenhouse gas emissions	1	2	3
Landfill life expectancy	1	2	3
Social and institutional			
Affordability	3	2	1
Acceptability	3	3	3
Capacity	3	2	1
Score	**17**	**15**	**13**

STRATEGIC PLAN



STRATEGIC PLAN



9 targets in 3 time scales according to cost and market demands:

- Short term (0-5 years);
- Medium term (5-10 years);
- Long term (10-15 years).

Each target related with one of the physical elements of SWM system:

- Generation
- Collection
- Treatment
- Disposal
- Resource value

Deseavantiga Secretary of Environment will monitor

TARGETS FOR A GREENER DESEAVANTIGA

Generation
Collection
Treatment
Disposal
Resourse value

Target #1
Reduce waste generation
Short: 1% reduction per year
Medium: 1% reduction per year

Target #2
Increase waste collection coverage
Short: 85% (urban); 50% (rural)
Medium: 95% (urban); 70% (rural)
Long: 95% (urban); 80% (rural)

Target #3
Improve reliability of waste collection services
Short: 99% of reliability

TARGETS FOR A GREENER DESEAVANTIGA

- Generation
- Collection
- Treatment
- Disposal
- Resourse value

Target #4

Improve treatment of industrial waste generated by the tanneries and slaughterhouses

Short: The water treatment of the tanneries and slaughterhouses follows the regulation standards

Medium: At least 50% of organic waste from the tanneries and slaughterhouses composted or digested in biogas plants

Long: 100% of organic waste from the tanneries and slaughterhouses composted

or digested in biogas plants

Target #5

Encourage household waste segregation to ensure clean waste flows

Short: 2-flow system effective for 10% of HHs

Medium: 2-flow system effective for 30% of HHs

Long: 2-flow system effective for 50% of HHs

TARGETS FOR A GREENER DESEAVANTIGA

- Generation
- Collection
- Treatment
- Disposal
- Resourse value

Target #6

Establish and construct infrastructure for waste treatment

Short: Construct a controlled final disposal site for the waste

Remediate existing dumpsites

Medium: Construct a facility to sort collected waste and reduce its volume before sending to final disposal

Long: Construct a plant to treat organic waste and its emissions

Target #7

Limit greenhouse gas emissions

Short: Reduce CO_2 equivalent emissions by 30%

Medium: Reduce CO_2 equivalent emissions by 20%

Long: Reduce CO_2 equivalent emissions by 15%

TARGETS FOR A GREENER DESEAVANTIGA

Generation
Collection
Treatment
Disposal
Resourse value

Target #8

Reduce volume of waste disposed in the sanitary landfill

Short: 0%

Medium: 25%

Long: 50%

Target #9

Increase recycling rates

Short: 1% increase of overall recycling per year

Medium: 2% increase for overall recycling per year (for the 3 first years only)

3. Financial Analysis

Comparison of 3 scenarios

	Landfill	Landfill +MBT	Landfill+MBT +Biogas (MBT = 2017, Biogas = 2019)
Revenue	**$ 563,895,001**	**$ 563,895,001**	**$ 563,895,001**
Costs			
CAPEX			
Collection	$ 4,541,329	$ 4,541,329	$ 4,541,329
Transfer	$ 1,783,445	$ 1,783,445	$ 1,783,445
Landfill	$ 4,490,113	$ 4,490,113	$ 4,490,113
MBT		$ 85,100,409	$ 85,100,409
Biogas			$ 28,208,649
OPEX			
Collection	$ 97,610,681	$ 97,610,681	$ 97,610,681
Transfer	$ 36,225,467	$ 36,225,467	$ 36,225,467
Landfill	$ 69,540,519	$ 69,540,519	$ 69,540,519
MBT		$ 72,418,218	$ 72,418,218
Biogas			$ 81,399,923
Other	$ 18,506,106	$ 18,506,106	$ 18,506,106
Total Expense	**$ 232,697,660**	**$ 390,216,288**	**$ 499,824,860**
Net Income	**$ 212,044,280**	**$ 175,685,433**	**$ 134,414,268**
FIRR (2016 - 36)	**81.14%**	**19.10%**	**8.78%**

Exorbitant FIRR for Scenario 1

Tariff Comparison - 3 scenarios

Landfill

Monthly

		Monthly Tariff	Weighted cost	Annual Tariff	
Poor	30%	$ 0.75	0.225	$ 9	
Medium - low income	40%	$ 1.50	0.6	$ 18	
Medium - high income	20%	$ 2.50	0.5	$ 30	
Commercial, industrial and high income	10%	$ 2.75	0.275	$ 33	
Rural		$ 0.75		$ 9	

Landfill+MBT

		Monthly Tariff	Weight cost
Poor	30%	$ 1.75	0.
Medium - low income	40%	$ 2.20	
Medium - high income	20%	$ 3.50	
Commercial, industrial and high income	10%	$ 4.50	
Rural		$ 1.00	

Landfill+MBT+Biogas

		Monthly Tariff	Weighted cost	Annual Tariff	
Poor	30%	$ 2.00	0.6	$ 24	
Medium - low income	40%	$ 3.00	1.2	$ 36	
Medium - high income	20%	$ 3.50	0.7	$ 42	
Commercial, industrial and high income	10%	$ 5.00	0.5	$ 60	
Rural		$ 1.00		$ 12	
			3.00	$ 36	0.55%

Annual

	Landfill	Landfill +MBT	Landfill+MBT+ Biogas
Poor	$ 9	$ 21	$ 24
Medium - low income	$ 18	$ 26	$ 36
Medium - high income	$ 30	$ 42	$ 42
Commercial, industrial and high income	$ 33	$ 54	$ 60
Rural	$ 9	$ 12	$ 12
% of Income	0.30%	0.47%	0.55%
FIRR	**12.44%**	**10.92%**	**8.78%**

NEXT STEPS

- Decision making on preferred scenario
- Land acquisition
- Develop and implement communciations and engagement strategy
- Identify partner for capacity building
- Establish regional utility (legislation, resourcing, etc..)
- Secure funding/financing

THANK YOU!