# ONE MAN'S GARBAGE IS ANOTHER MAN'S GOLD TURNING GARBAGE INTO ELECTRICITY

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E-Flow (Thailand) Co. Ltd.





### LANDFILL GAS

- Produced with solid waste decomposition
- Amount & composition dependent on solid waste characteristics
- Increase in organics equals an increase in gas generation
- Can be used to create energy
- Gas production ends with end of decomposition

### LANDFILL GAS: TYPICAL COMPOSITION

### Methane (CH<sub>4</sub>)

**50%** to 60%

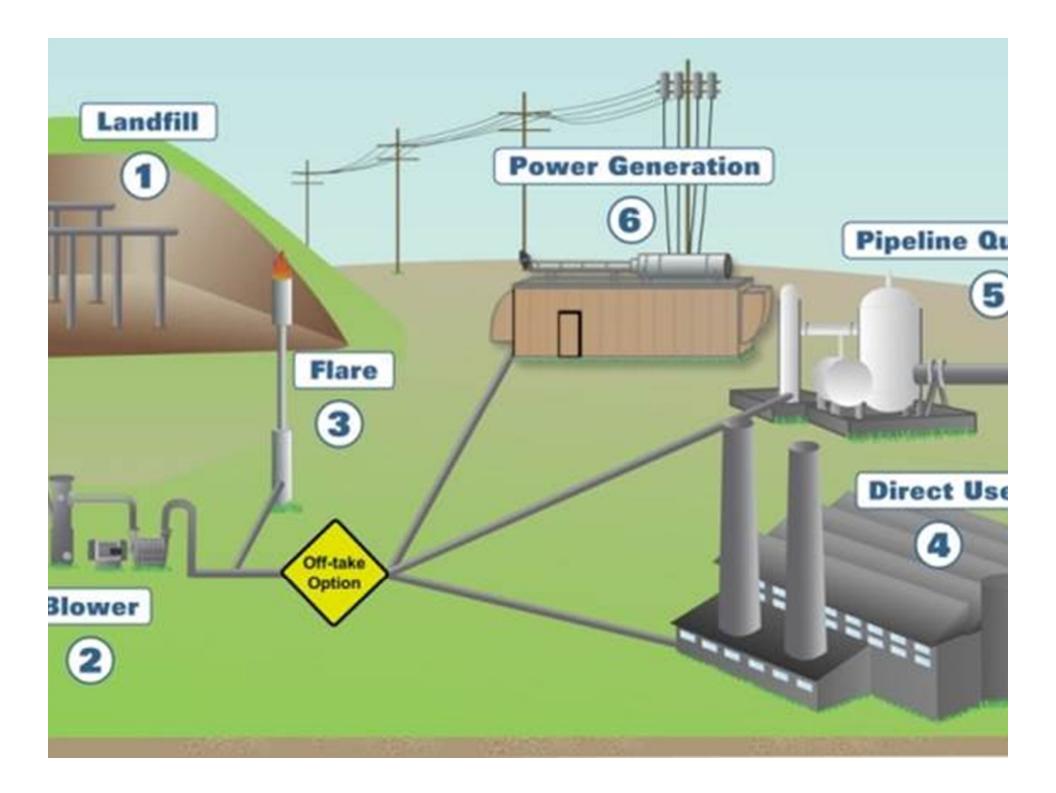
### Carbon Dioxide (CO<sub>2</sub>)

**40%** to 50%

### **Electricity Generation**

 670 m3/hr of LFG (50% methane) will generate 1.02 MW electricity









## ELEMENTS OF AN LFG COLLECTION SYSTEM

### **LFG** collection points

- Vertical extraction wells
- Horizontal collectors/trenches

### **Condensate management**

LFG blower/combustion station (flare, engine, etc.)

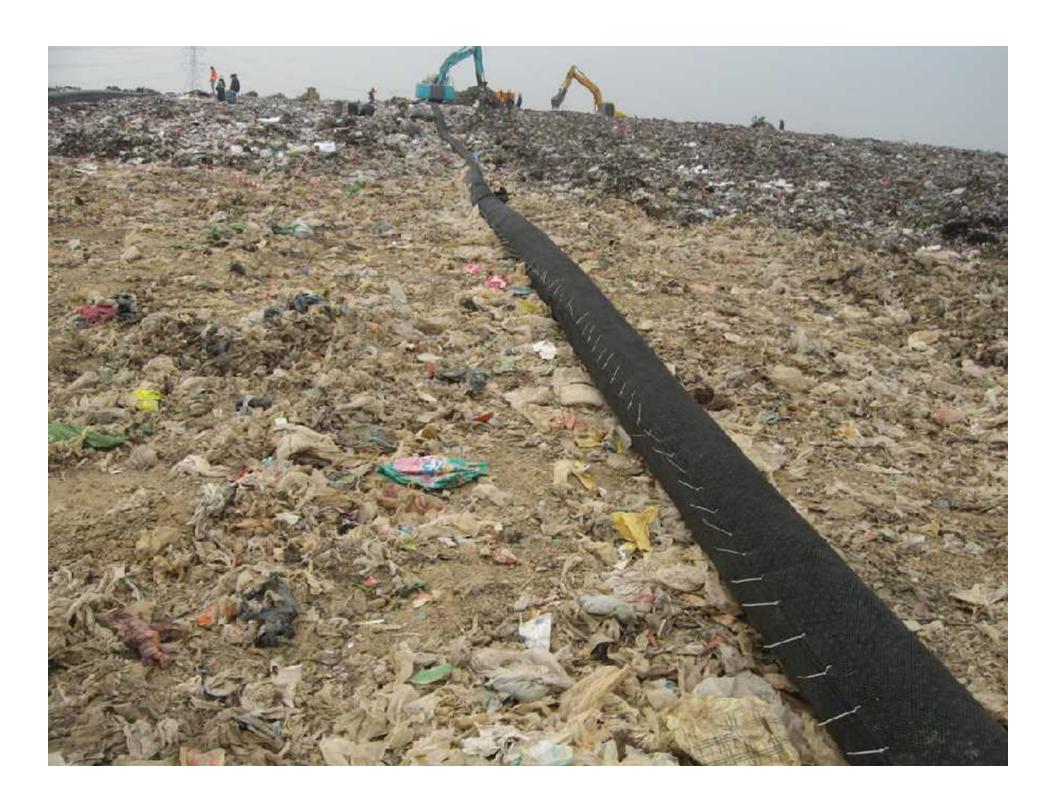
### LFG COLLECTION WELLS

### **Horizontal Wells**

Installed during landfill filling

### **Vertical Wells**

Installed during/after landfill filling

















### CONDENSATE

- Liquid product of the cooling of the water vapor present in the landfill gas flow.
- Consequences of improper handling of condensate liquids
  - Flooded LFG wells.
  - Poor vacuum in the wells.
  - Partial/Complete blockage of the gas collection system.
  - Increased operations costs.

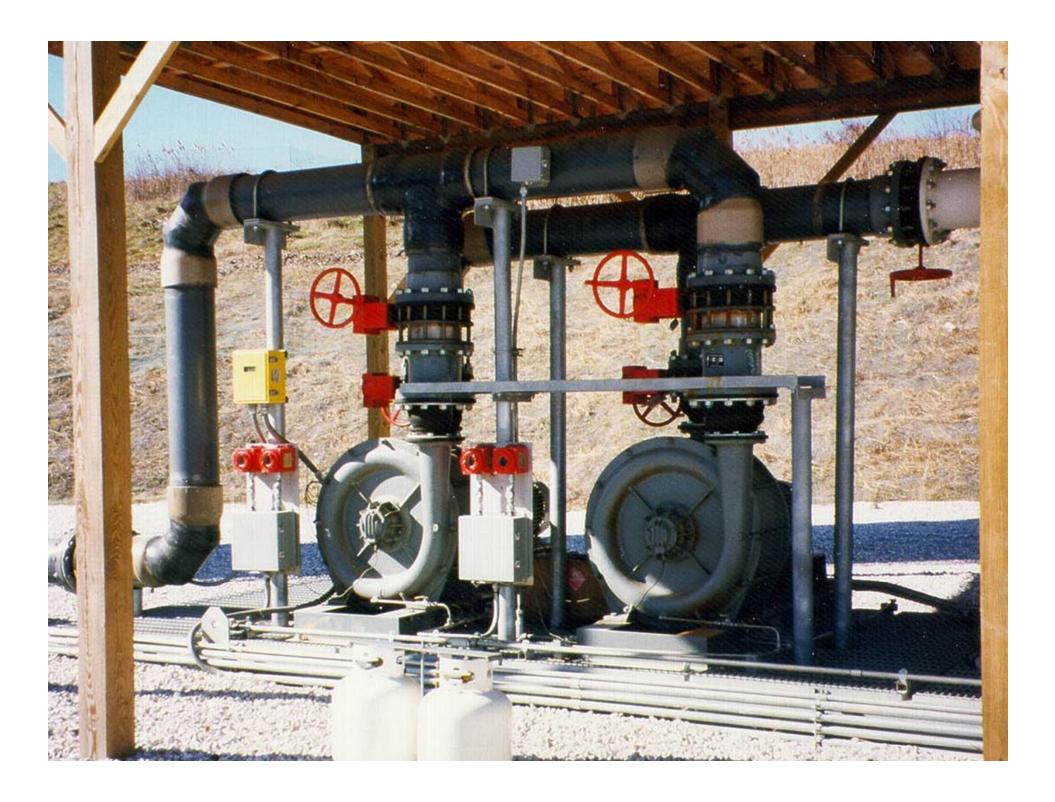
### **Condensate Sump**



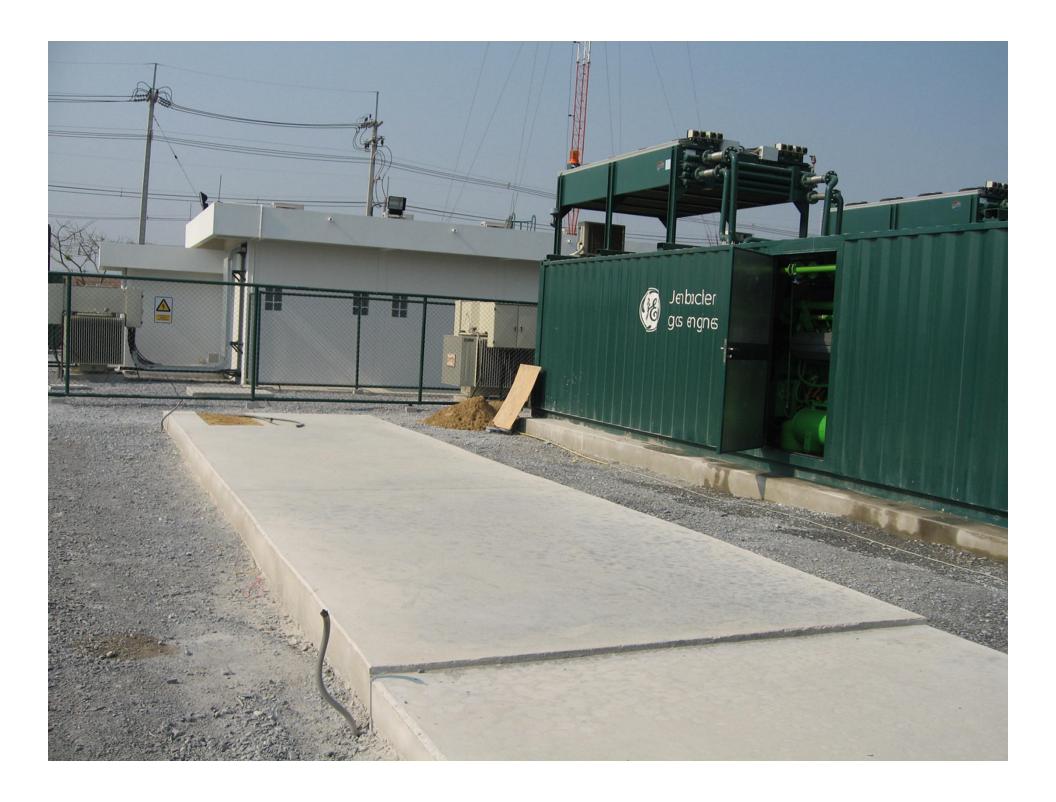
Laterals













### MODEL LFG PRODUCTION

## Theoretical landfill Say Chiang Mai

Population = 200,000 (source Wikipedia)

MSW production = 0.6 kg/person/day (PCD Report)

120 Tonnes/day (logically it is more)

### U.S. EPA LANDGEM V. 3.02

Landfill gas emissions model (v. 3.02, 2005) – first-order decay LFG generation equation:

$$Q_{CH_4} = \sum_{i=1}^{n} \sum_{j=0.1}^{1} k L_o \left( \frac{M_i}{10} \right) e^{-kt_{ij}}$$

- ${ullet} Q_{CH_4} = Methane emission rate$
- M = annual waste disposal (tonnes)
- k = methane generation (decay) rate (1/year)
- Lo = potential methane generation capacity (m³/tonne)

Default k and Lo values developed for U.S. landfills: (wet vs. dry sites)

### COUNTRY-SPECIFIC MODELS DEVELOPED BY GMI **Central America LFG Model China LFG Model** Colombia LFG Model **Ecuador LFG Model** Mexico LFG Model v.2 **Philippines LFG Model**

**Thailand LFG Model** 

**Ukraine LFG Model** 

### Clear ALL Non-Parameter Inputs/Selections

### 1: PROVIDE LANDFILL CHARACTERISTICS

Landfill Closure Year entered is not used by the model Landfill Open Year 2013 unless 'Have Model Calculate Closure Year?' option is **Landfill Closure Year** 2022 No. Yes ○ No Have Model Calculate Closure Year? Waste Design Capacity 448,950 megagrams

> Restore Default Model **Parameters**

### 2: DETERMINE MODEL PARAMETERS

Methane Generation Rate, k (year-1)	User-spe	ecified k value should be l	ased on site-s	pecific data and determined
User-specified	•	User-specified value:	0.170	by EPA Method 2E.
Potential Methane Generation Capaci	ty, L <sub>o</sub> (m	1 <sup>3</sup> /Mg) User-specified	Lo value shoul	
User-specified	•	User-specified value:	54	data and determined by waste type and composition.
NMOC Concentration (ppmv as hexane	)			
Inventory No or Unknown Co-disposal -	600 🔻			
Methane Content (% by volume)				
CAA - 50% by volume	<b>-</b>			

### 4: ENTER WASTE ACCEPTANCE RAT

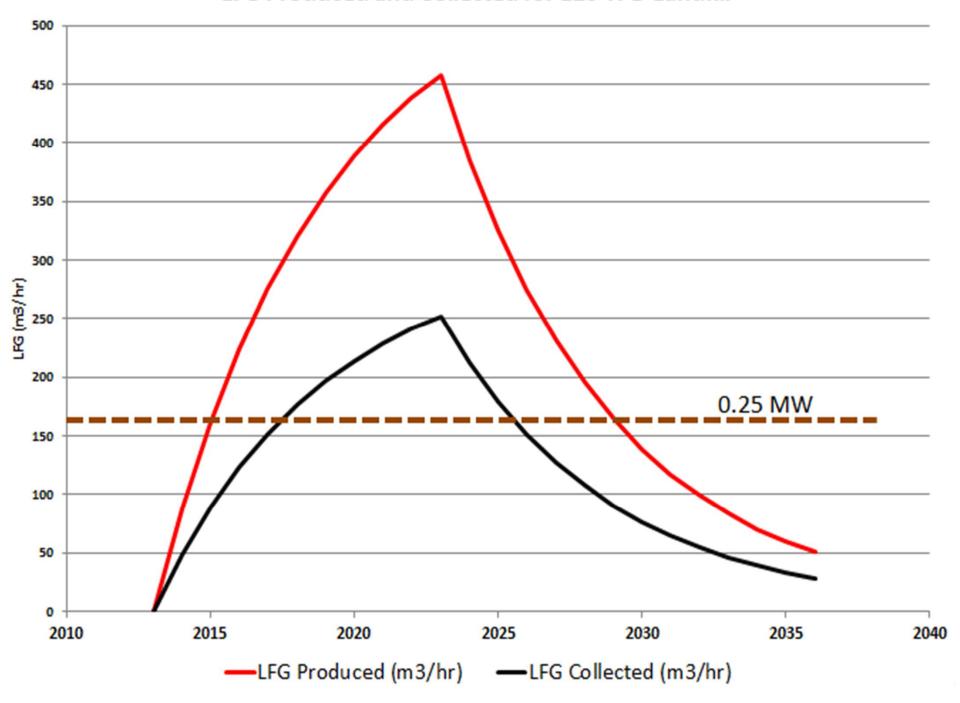
Mg/year Input Units:

Year	Input Units	Calculated Unit
Teal	(Mg/year)	(short tons/year)
2013	44,895	49,38
2014	44,895	49,38
2015	44,895	49,38
2016	44,895	49,38
2017	44,895	49,38
2018	44,895	49,38
2019	44,895	49,38
2020	44,895	49,38
2021	44,895	49,38
2022	44,895	49,38
2023		
2024	0	
2025	0	

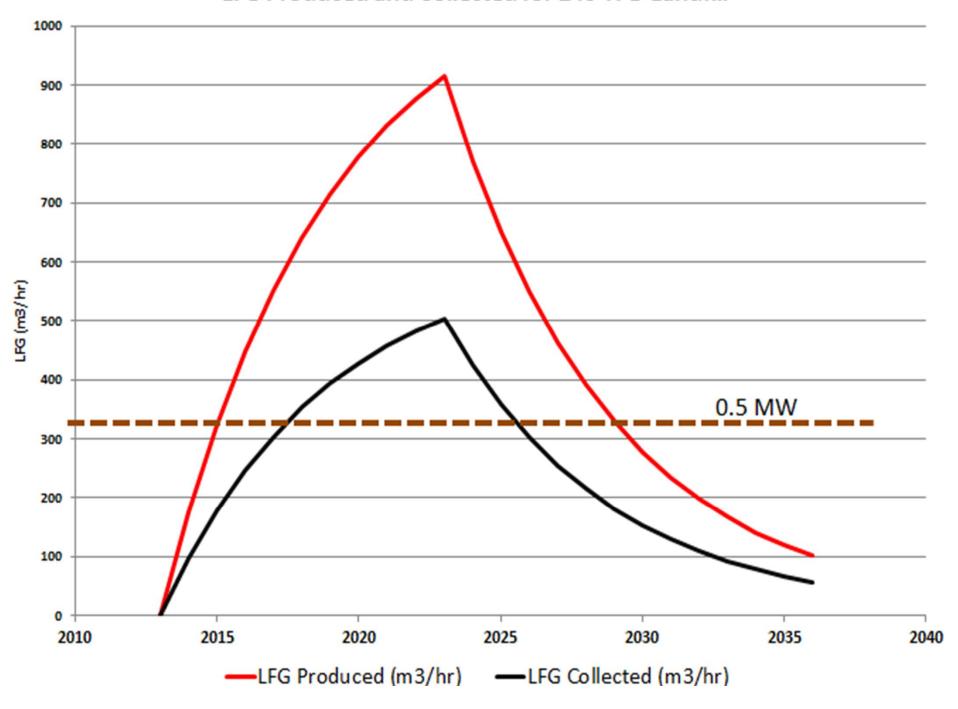
.	50 % by volume			User-specified Unit:	av ft^3/min
	Waste	e-In-Place		Total landfill gas	
Year	(Mg)	(short tons)	(Mg/year)	(m³/year)	(av ft^3/min)
2013	0	0	0	Ó	0
2014	44,895	49,385	9.565E+02	7.659E+05	5.146E+01
2015	89,790	98,769	1.763E+03	1.412E+06	9.488E+01
2016	134,685	148,154	2.444E+03	1.957E+06	1.315E+02
2017	179,580	197,538	3.019E+03	2.417E+06	1.624E+02
2018	224,475	246,923	3.503E+03	2.805E+06	1.885E+02
2019	269,370	296,307	3.912E+03	3.132E+06	2.105E+02
2020	314,265	345,692	4.257E+03	3.409E+06	2.290E+02
2021	359,160	395,076	4.548E+03	3.642E+06	2.447E+02
2022	404,055	444,461	4.793E+03	3.838E+06	2.579E+02
2023	448,950	493,845	5.000E+03	4.004E+06	2.690E+02
2024	448,950	493,845	4.219E+03	3.378E+06	2.270E+02
2025	448,950	493,845	3.559E+03	2.850E+06	1.915E+02
2026	448,950	493,845	3.003E+03	2.404E+06	1.616E+02
2027	448,950	493,845	2.533E+03	2.029E+06	1.363E+02
2028	448,950	493,845	2.137E+03	1.711E+06	1.150E+02
2029	448,950	493,845	1.803E+03	1.444E+06	9.701E+01
2030	448,950	493,845	1.521E+03	1.218E+06	8.185E+01
2031	448,950	493,845	1.283E+03	1.028E+06	6.905E+01
2032	448,950	493,845	1.083E+03	8.670E+05	5.826E+01
2033	448,950	493,845	9.135E+02	7.315E+05	4.915E+01
2034	448,950	493,845	7.707E+02	6.171E+05	4.146E+01
2035	448,950	493,845	6.502E+02	5.206E+05	3.498E+01
2036	448,950	493,845	5.485E+02	4.392E+05	2.951E+01
2037	448,950	493,845	4.628E+02	3.706E+05	2.490E+01
2038	448,950	493,845	3.904E+02	3.126E+05	2.101E+01
2039	448,950	493,845	3.294E+02	2.638E+05	1.772E+01
2040	448,950	493,845	2.779E+02	2.225E+05	1.495E+01

	120 Tonne/day				240	Tonne/da	у			
Year	m3/yr	m3/hr	Efficiency	Collected	MW	m3/yr	m3/hr	Efficiency	Collected	MW
2013	0.00	0.00	55%	0.00	0.00	0.00	0.00	0.55	0.00	0.00
2014	765,893.24	87.43	55%	48.09	0.07	1,531,786.48	174.86	0.55	96.17	0.14
2015	1,412,050.42	161.19	55%	88.66	0.13	2,824,100.85	322.39	0.55	177.31	0.26
2016	1,957,190.50	223.42	55%	122.88	0.18	3,914,381.01	446.85	0.55	245.77	0.37
2017	2,417,106.01	275.93	55%	151.76	0.23	4,834,212.02	551.85	0.55	303.52	0.45
2018	2,805,120.54	320.22	55%	176.12	0.26	5,610,241.08	640.44	0.55	352.24	0.53
2019	3,132,474.75	357.59	55%	196.67	0.29	6,264,949.50	715.18	0.55	393.35	0.59
2020	3,408,651.98	389.12	55%	214.01	0.32	6,817,303.95	778.23	0.55	428.03	0.64
2021	3,641,652.99	415.71	55%	228.64	0.34	7,283,305.97	831.43	0.55	457.29	0.68
2022	3,838,227.74	438.15	55%	240.98	0.36	7,676,455.48	876.31	0.55	481.97	0.72
2023	4,004,070.95	457.09	55%	251.40	0.38	8,008,141.89	914.17	0.55	502.79	0.75
2024	3,378,093.78	385.63	55%	212.09	0.32	6,756,187.56	771.25	0.55	424.19	0.63
2025	2,849,978.87	325.34	55%	178.94	0.27	5,699,957.74	650.68	0.55	357.87	0.53
2026	2,404,426.90	274.48	55%	150.96	0.23	4,808,853.80	548.96	0.55	301.93	0.45
2027	2,028,530.38	231.57	55%	127.36	0.19	4,057,060.76	463.13	0.55	254.72	0.38
2028	1,711,399.71	195.37	55%	107.45	0.16	3,422,799.42	390.73	0.55	214.90	0.32
2029	1,443,847.72	164.82	55%	90.65	0.14	2,887,695.45	329.65	0.55	181.31	0.27
2030	1,218,123.52	139.06	55%	76.48	0.11	2,436,247.05	278.11	0.55	152.96	0.23
2031	1,027,687.96	117.32	55%	64.52	0.10	2,055,375.92	234.63	0.55	129.05	0.19
2032	867,024.17	98.98	55%	54.44	0.08	1,734,048.35	197.95	0.55	108.87	0.16
2033	731,477.79	83.50	55%	45.93	0.07	1,462,955.58	167.00	0.55	91.85	0.14
2034	617,122.08	70.45	55%	38.75	0.06	1,234,244.15	140.90	0.55	77.49	0.12
2035	520,644.18	59.43	55%	32.69	0.05	1,041,288.37	118.87	0.55	65.38	0.10
2036	439,249.18	50.14	55%	27.58	0.04	878,498.36	100.29	0.55	55.16	0.08

### LFG Produced and Collected for 120 TPD Landfill



### LFG Produced and Collected for 240 TPD Landfill



Electricity savings (offset replacement from PEA)					
	120 To	nnes/day	240 Tonnes/day		
Year	KWH	Baht (3.24/kwh)	KWH	Baht (3.24/kwh)	
2013	0	0	0	0	
2014	628,718	2,037,047	1,257,437	4,074,095	
2015	1,159,146	3,755,633	2,318,292	7,511,265	
2016	1,606,649	5,205,543	3,213,298	10,411,085	
2017	1,984,192	6,428,780	3,968,383	12,857,561	
2018	2,302,711	7,460,783	4,605,422	14,921,567	
2019	2,571,434	8,331,448	5,142,869	16,662,896	
2020	2,798,147	9,065,997	5,596,294	18,131,994	
2021	2,989,417	9,685,710	5,978,833	19,371,420	
2022	3,150,784	10,208,540	6,301,568	20,417,080	
2023	3,286,924	10,649,633	6,573,848	21,299,267	
2024	2,773,062	8,984,721	5,546,124	17,969,442	
2025	2,339,535	7,580,093	4,679,070	15,160,186	
2026	1,973,783	6,395,058	3,947,567	12,790,116	
2027	1,665,212	5,395,285	3,330,423	10,790,571	
2028	1,404,880	4,551,812	2,809,761	9,103,625	
2029	1,185,248	3,840,204	2,370,496	7,680,408	
2030	999,952	3,239,845	1,999,904	6,479,690	
2031	843,624	2,733,343	1,687,249	5,466,686	
2032	711,736	2,306,025	1,423,473	4,612,051	
2033	600,467	1,945,513	1,200,934	3,891,025	
2034	506,593	1,641,361	1,013,185	3,282,721	
2035	427,394	1,384,758	854,789	2,769,516	
Total	37,909,609	122,827,133	75,819,218	245,654,265	

### TYPICAL ELECTRIC PROJECT COMPONENTS & COSTS (US)

### 1 MW engine project

Total capital cost = ~\$1.6 million

~THB 50,000,000

 Includes: LFG compression and treatment, engine/generator, electrical switchgear

### Operation and maintenance costs =

- ~\$175,000/year
- ~THB 5,600,000

	120 TPD Landfill Financing (Thai Baht)					
Year	Income	Cummulative	Expense	Cummulative	Net	
2013	0	0	50,000,000	50,000,000	-50,000,000	
2014	2,037,047	2,037,047	5,600,000	55,600,000	-53,562,953	
2015	3,755,633	5,792,680	5,600,000	61,200,000	-55,407,320	
2016	5,205,543	10,998,223	5,600,000	66,800,000	-55,801,777	
2017	6,428,780	17,427,003	5,600,000	72,400,000	-54,972,997	
2018	7,460,783	24,887,786	5,600,000	78,000,000	-53,112,214	
2019	8,331,448	33,219,234	5,600,000	83,600,000	-50,380,766	
2020	9,065,997	42,285,231	5,600,000	89,200,000	-46,914,769	
2021	9,685,710	51,970,941	5,600,000	94,800,000	-42,829,059	
2022	10,208,540	62,179,481	5,600,000	100,400,000	-38,220,519	
2023	10,649,633	72,829,114	5,600,000	106,000,000	-33,170,886	
2024	8,984,721	81,813,835	5,600,000	111,600,000	-29,786,165	
2025	7,580,093	89,393,928	5,600,000	117,200,000	-27,806,072	
2026	6,395,058	95,788,986	5,600,000	122,800,000	-27,011,014	
2027	5,395,285	101,184,271	5,600,000	128,400,000	-27,215,729	
2028	4,551,812	105,736,084	5,600,000	134,000,000	-28,263,916	
2029	3,840,204	109,576,288	5,600,000	139,600,000	-30,023,712	
2030	3,239,845	112,816,133	5,600,000	145,200,000	-32,383,867	
2031	2,733,343	115,549,476	5,600,000	150,800,000	-35,250,524	
2032	2,306,025	117,855,501	5,600,000	156,400,000	-38,544,499	
2033	1,945,513	119,801,014	5,600,000	162,000,000	-42,198,986	
2034	1,641,361	121,442,374	5,600,000	167,600,000	-46,157,626	
2035	1,384,758	122,827,133	5,600,000	173,200,000	-50,372,867	

	240 TPD Landfill Financing (Thai Baht)					
Year	Income	Cummulative	Expense	Cummulative	Net	
2013	0	0	50,000,000	50,000,000	-50,000,000	
2014	4,074,095	4,074,095	5,600,000	55,600,000	-51,525,905	
2015	7,511,265	11,585,360	5,600,000	61,200,000	-49,614,640	
2016	10,411,085	21,996,445	5,600,000	66,800,000	-44,803,555	
2017	12,857,561	34,854,006	5,600,000	72,400,000	-37,545,994	
2018	14,921,567	49,775,573	5,600,000	78,000,000	-28,224,427	
2019	16,662,896	66,438,468	5,600,000	83,600,000	-17,161,532	
2020	18,131,994	84,570,462	5,600,000	89,200,000	-4,629,538	
2021	19,371,420	103,941,881	5,600,000	94,800,000	9,141,881	
2022	20,417,080	124,358,961	5,600,000	100,400,000	23,958,961	
2023	21,299,267	145,658,228	5,600,000	106,000,000	39,658,228	
2024	17,969,442	163,627,671	5,600,000	111,600,000	52,027,671	
2025	15,160,186	178,787,857	5,600,000	117,200,000	61,587,857	
2026	12,790,116	191,577,972	5,600,000	122,800,000	68,777,972	
2027	10,790,571	202,368,543	5,600,000	128,400,000	73,968,543	
2028	9,103,625	211,472,168	5,600,000	134,000,000	77,472,168	
2029	7,680,408	219,152,575	5,600,000	139,600,000	79,552,575	
2030	6,479,690	225,632,265	5,600,000	145,200,000	80,432,265	
2031	5,466,686	231,098,952	5,600,000	150,800,000	80,298,952	
2032	4,612,051	235,711,003	5,600,000	156,400,000	79,311,003	
2033	3,891,025	239,602,028	5,600,000	162,000,000	77,602,028	
2034	3,282,721	242,884,749	5,600,000	167,600,000	75,284,749	
2035	2,769,516	245,654,265	5,600,000	173,200,000	72,454,265	

### **SELL TO THE GRID**

Connect to the grid

Get a 2.5 Bt/kwh adder

Ignoring income from Demand, ToU, ToD

Electricity savings (Sold to the grid (2.5 Bt/kwh adder))					
	120 T	onnes/day	240 To	nnes/day	
Year	KWH	Baht (5.74/kwh)	KWH	Baht (5.74/kwh)	
2013	0	0	0	0	
2014	628,718	3,608,843	1,257,437	7,217,686	
2015	1,159,146	6,653,497	2,318,292	13,306,995	
2016	1,606,649	9,222,165	3,213,298	18,444,330	
2017	1,984,192	11,389,259	3,968,383	22,778,518	
2018	2,302,711	13,217,561	4,605,422	26,435,121	
2019	2,571,434	14,760,034	5,142,869	29,520,068	
2020	2,798,147	16,061,365	5,596,294	32,122,729	
2021	2,989,417	17,159,251	5,978,833	34,318,503	
2022	3,150,784	18,085,500	6,301,568	36,171,000	
2023	3,286,924	18,866,943	6,573,848	37,733,886	
2024	2,773,062	15,917,376	5,546,124	31,834,752	
2025	2,339,535	13,428,930	4,679,070	26,857,861	
2026	1,973,783	11,329,516	3,947,567	22,659,032	
2027	1,665,212	9,558,314	3,330,423	19,116,628	
2028	1,404,880	8,064,013	2,809,761	16,128,027	
2029	1,185,248	6,803,324	2,370,496	13,606,649	
2030	999,952	5,739,725	1,999,904	11,479,451	
2031	843,624	4,842,404	1,687,249	9,684,809	
2032	711,736	4,085,366	1,423,473	8,170,732	
2033	600,467	3,446,680	1,200,934	6,893,359	
2034	506,593	2,907,842	1,013,185	5,815,685	
2035	427,394	2,453,244	854,789	4,906,489	
Total	37,909,609	217,601,155	75,819,218	435,202,309	

12	120 TPD Landfill Financing with 2.5 Bt/kwh adder (Thai Baht)						
Year	Income	Cummulative	Expense	Cummulative	Net		
2013	0	0	70,000,000	70,000,000	-70,000,000		
2014	3,608,843	3,608,843	5,600,000	75,600,000	-71,991,157		
2015	6,653,497	10,262,341	5,600,000	81,200,000	-70,937,659		
2016	9,222,165	19,484,505	5,600,000	86,800,000	-67,315,495		
2017	11,389,259	30,873,765	5,600,000	92,400,000	-61,526,235		
2018	13,217,561	44,091,325	5,600,000	98,000,000	-53,908,675		
2019	14,760,034	58,851,359	5,600,000	103,600,000	-44,748,641		
2020	16,061,365	74,912,724	5,600,000	109,200,000	-34,287,276		
2021	17,159,251	92,071,975	5,600,000	114,800,000	-22,728,025		
2022	18,085,500	110,157,475	5,600,000	120,400,000	-10,242,525		
2023	18,866,943	129,024,418	5,600,000	126,000,000	3,024,418		
2024	15,917,376	144,941,795	5,600,000	131,600,000	13,341,795		
2025	13,428,930	158,370,725	5,600,000	137,200,000	21,170,725		
2026	11,329,516	169,700,241	5,600,000	142,800,000	26,900,241		
2027	9,558,314	179,258,555	5,600,000	148,400,000	30,858,555		
2028	8,064,013	187,322,568	5,600,000	154,000,000	33,322,568		
2029	6,803,324	194,125,892	5,600,000	159,600,000	34,525,892		
2030	5,739,725	199,865,618	5,600,000	165,200,000	34,665,618		
2031	4,842,404	204,708,022	5,600,000	170,800,000	33,908,022		
2032	4,085,366	208,793,388	5,600,000	176,400,000	32,393,388		
2033	3,446,680	212,240,068	5,600,000	182,000,000	30,240,068		
2034	2,907,842	215,147,910	5,600,000	187,600,000	27,547,910		
2035	2,453,244	217,601,155	5,600,000	193,200,000	24,401,155		

24	0 TPD Landf	ill Financing wi	th 2.5 Bt/kw	/h adder (Thai	240 TPD Landfill Financing with 2.5 Bt/kwh adder (Thai Baht)						
Year	Income	Cummulative	Expense	Cummulative	Net						
2013	0	0	70,000,000	70,000,000	-70,000,000						
2014	7,217,686	7,217,686	5,600,000	75,600,000	-68,382,314						
2015	13,306,995	20,524,681	5,600,000	81,200,000	-60,675,319						
2016	18,444,330	38,969,011	5,600,000	86,800,000	-47,830,989						
2017	22,778,518	61,747,529	5,600,000	92,400,000	-30,652,471						
2018	26,435,121	88,182,650	5,600,000	98,000,000	-9,817,350						
2019	29,520,068	117,702,718	5,600,000	103,600,000	14,102,718						
2020	32,122,729	149,825,447	5,600,000	109,200,000	40,625,447						
2021	34,318,503	184,143,950	5,600,000	114,800,000	69,343,950						
2022	36,171,000	220,314,950	5,600,000	120,400,000	99,914,950						
2023	37,733,886	258,048,837	5,600,000	126,000,000	132,048,837						
2024	31,834,752	289,883,589	5,600,000	131,600,000	158,283,589						
2025	26,857,861	316,741,450	5,600,000	137,200,000	179,541,450						
2026	22,659,032	339,400,482	5,600,000	142,800,000	196,600,482						
2027	19,116,628	358,517,110	5,600,000	148,400,000	210,117,110						
2028	16,128,027	374,645,136	5,600,000	154,000,000	220,645,136						
2029	13,606,649	388,251,785	5,600,000	159,600,000	228,651,785						
2030	11,479,451	399,731,236	5,600,000	165,200,000	234,531,236						
2031	9,684,809	409,416,044	5,600,000	170,800,000	238,616,044						
2032	8,170,732	417,586,776	5,600,000	176,400,000	241,186,776						
2033	6,893,359	424,480,136	5,600,000	182,000,000	242,480,136						
2034	5,815,685	430,295,821	5,600,000	187,600,000	242,695,821						
2035	4,906,489	435,202,309	5,600,000	193,200,000	242,002,309						

### CONCLUSIONS

LFG to energy is possible; Environmentally good Financially possible

Scale is important e.g. Bangkok has >3,000 tons/day-8 MW

