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# China Landfill Gas Model

## Version 1.1

**Bryce Lloyd**
**Organic Waste Technologies (Hong Kong) Limited**

LANDFILL METHANE OUTREACH PROGRAM

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# China Landfill Gas Model Version 1.1

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Prepared for:

Methane to Markets, and the

U.S. Environmental Protection Agency - Landfill Methane Outreach Program (LMOP)

Prepared by:

Eastern Research Group, Inc., and

Organic Waste Technologies (Hong Kong) Ltd.

# China Landfill Gas Model Version 1.1

LFG Modeling – Science vs. Art

Recent CDM Experience – over-estimation vs. under-delivery

Purpose - provide landfill owners, operators, and developers with a realistic tool to evaluate the feasibility and potential benefits of recovering and utilizing LFG for production of energy for various potential end uses

# China Landfill Gas Model Version 1.1

- Estimates potential LFG generation and recovery potential for existing or future municipal solid waste (MSW) landfills in China
- Estimates available emission reductions
- Provides estimates of energy output from either a direct use project or an electrical power generation project

# China Landfill Gas Model Version 1.1

- Excel® spreadsheet model
  - Based on USEPA LandGEM
- Based on a first order decay rate equation
- Requires the user to input site-specific data for
  - landfill location (in terms of geographical climate zones)
  - approximate coal ash content of the waste
  - history of landfill fires
  - a number of landfill characteristics that determine collection efficiency

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# China Landfill Gas Model Version 1.1

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- Based on the user's input for geographical location (climate considerations), and waste composition data specific to various regions of China, the model calculates recommended values for the following parameters:
  - k
  - $L_0$

# China Landfill Gas Model Version 1.1

- Requires the user to input site-specific data for:
  - geographic location
  - landfill opening and closing years
  - refuse disposal rates
  - estimated collection efficiency and area coverage of the LFG collection system
  - coal ash
  - fires

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- The model estimates LFG generation and recovery rates using parameters  based on the following factors:
  - geographical selection and climate conditions - IPCC calculations for k and $L_0$
  - collection efficiency and area coverage
  - coal ash and fire discount factors
  - user input for waste disposal rates
- allows user  to override default parameters

# China Landfill Gas Model Version 1.1

- The recommended values for model parameters were developed using data on China's
  - Climate regions
  - Waste characteristics
  - Waste composition
  - Waste disposal practices
  - Observed landfill operating conditions

# China Landfill Gas Model Version 1.1

- Actual LFG recovery rates from four landfills in China were evaluated
- Data scatter led to the conclusion that insufficient data were available to accurately calibrate the model results to actual reported LFG recovery rates
- Limited recovery data were available and many sites were unwilling to provide actual recovery data

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# Climate Zones in China

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- Locations in China are categorized as “cold or hot” and “dry or wet”
- Based on the following two criteria in accordance with Table 3.4 in the IPCC 2006 Guidelines

# Climate Zones in China

**Cold vs. Hot:**

- “Cold” if mean annual temperature (MAT) < 20$^{o}$C
- “Hot” if MAT > 20$^{o}$C

**Dry vs. Wet:**

- For “hot” locations,
  - “Dry” if mean annual precipitation (MAP) < 1000mm
  - “Wet” if MAP > 1000mm
- For “cold” locations,
  - “Dry” if ratio of mean annual precipitation to potential evapo-transpiration (PET), or MAP/PET, < 1
  - “Wet” if MAP/PET > 1

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# Climate Zones in China

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- Using the above two criteria, each location in China can be classified as belonging to one of the following three climatic zones (or regions):
  - Region 1: Cold and Dry
  - Region 2: Cold and Wet
  - Region 3: Hot and Wet
- There are no “Hot and Dry” locations in China


Urumqi
Harbin
Changchun
Shenyang
Hohhot
Beijing
Tianjin
Shijianzhuang
Yinchuan
Taiyuan
Jinan
Xi'ning
Lanzhou
Xi'an
Zhengzhou
Nanjing
Shanghai
Hefei
Wuhan
Hang
-zhou
Lhasa
Chengdu
Chongqing
Nanchong
Changsha
Guiyang
Taipei
Xiamen
Kunming
Guangzhou
Nanning
Haikou
1
2
2
2
3
CLIMATE ZONE
1 COLD AND DRY
2 COLD AND WET
3 HOT AND WET

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# METHANE GENERATION RATE (k)

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- The recommended average k values for the three climatic zones are:

| Climatic Zone | k (per year) |
|---|---|
| Cold and Dry | 0.04 |
| Cold and Wet | 0.11 |
| Hot and Wet | 0.18 |

# ULTIMATE METHANE GENERATION POTENTIAL ($L_0$)

- Value of $L_0$ for each climatic zone based on available information on waste characteristics for landfills in each zone
- Value of $L_0$ reduced if landfill receives waste with significant amount of coal ash (>30%)

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# ULTIMATE METHANE GENERATION POTENTIAL ($L_0$)

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- The recommended $L_0$ values for the three climatic zones are:

| Climatic Zone | $L_0$ (m3/Mg) | |
|---|---|---|
| | Coal Ash Content <30% (Non-Coal-Based Landfill) | Coal Ash Content >30% (Coal-Based Landfill) |
| Cold and Dry | 70 | 35 |
| Cold and Wet | 56 | 28 |
| Hot and Wet | 56 | 42 |

# Fire Discount Factor

- If the user indicates that signs of current or past landfill fires were observed, the model will apply a default fire discount factor (30% percent reduction) to the LFG recovery estimate

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# Collection Efficiency

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Collection Efficiency

= (85% - x1 - x2 - x3 - x4 - x5 - x6 - x7) * ACF

Where

- x1 to x7 are discounts based on the landfill's construction and operation characteristics
- ACF, the Area Coverage Factor, is determined by the LFG System Area Coverage Percentage

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# Collection Efficiency

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| No. (i) | Question | Discount $x_i$ (%) | |
|---|---|---|---|
| | | Yes | No |
| 1 | Is the waste placed in the landfill properly compacted on an ongoing basis? | 0 | 3 |
| 2 | Does the landfill have a focused tipping area? | 0 | 5 |
| 3 | Are there leachate seeps appearing along the landfill sideslopes? Or is there ponding of water/leachate on the landfill surface? | 10 | 0 |

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# Collection Efficiency

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| No. (i) | Question | Discount, % ($x_i$) | |
|---|---|---|---|
| | | Yes | No |
| 4 | Is the average depth of waste 10m or greater? | 0 | 10 |
| 5 | Is any daily or weekly cover material applied to newly deposited waste? | 0 | 10 |
| 6 | Is any intermediate/final cover applied to areas of the landfill that have reached interim or final grade? | 0 | 5 |
| 7 | Does the landfill have a geosynthetic or clay liner? | 0 | 5 |

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# LFG System Area Coverage

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- The LFG System Area Coverage Percentage is defined as the percentage of the landfilled area that has a comprehensive and operating LFG collection system.
- Brackets I to V are defined in the table below.
- Area Coverage Factor (ACF) associated with each bracket.

# LFG System Area Coverage Percentage and Area Coverage Factor (ACF)

| LFG System Area Coverage Percentage | Bracket | Area Coverage Factor (ACF) |
|---|---|---|
| 80 – 100% | I | 0.95 |
| 60 – 80% | II | 0.75 |
| 40 – 60% | III | 0.55 |
| 20 – 40% | IV | 0.35 |
| < 20% | V | 0.15 |

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# Optional Input

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- Optional input:
  - User recommended value for:
    - k
    - $L_0$
    - Collection efficiency (can vary by year)
    - Supersedes model recommended parameters
    - Input only if reliable data are available
  - Actual measured recovery rate (plotted on output graph only; no calculations performed by model)

# Example

- Input
- Output table
- Output graph


China Model V1.1
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China Landfill Biogas Model
Version 1.1
November 2008
developed by:
U.S. Environmental Protection Agency
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# LMOP China LFG Model (v1.1)

Instructions

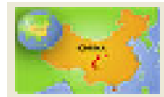
Please complete the information in the yellow highlighted cells. This information is the minimum input required for proper model operation.

**Input Parameters:**

| | | |
|---|---|---|
| Name/Title: | **Example Landfill, M2M Mexico Presentation** | **Edit title at left which feeds into the output table and graph.** |
| Location: | **Shenzhen City, Guangdong Province** | |
| Year Opened: | **1997** | **Input year landfill began receiving waste at left.** |
| Year Closed/Projected to Close: | **2010** | **Input closure year (i.e., the final year in which landfill will receive waste).** |
| Expected Methane Content of LFG: | **50%** | Please enter the expected methane content of the landfill gas. A value of 50% is recommended unless specific information is available from the site that warrants a different value. This value will be used to calculate the net flow of recovered gas. |

**Landfill Characteristics:**

| | |
|---|---|
| Region of China where the landfill is located (Identify from the map): | Region 3 (Hot and Wet) |
| Does coal ash make up a significant fraction (greater than 30% of the waste placed in the landfill? | No |
| Are there signs of current or past subsurface fires at the landfill? | No |



Show Regional Map

**Criteria Determining Collection Efficiency:**

| | | |
|---|---|---|
| 1. | Is the waste placed in the landfill properly compacted on an ongoing basis? | Yes |
| 2. | Does the landfill have a focused tipping area? | No |
| 3. | Are there leachate seeps appearing along the landfill sideslopes? Or is there ponding of water/leachate on the landfill surface? | No |
| 4. | Is the average depth of waste 10m or greater? | Yes |
| 5. | Is any daily or weekly cover material applied to newly deposited waste? | Yes |
| 6. | Is any intermediate/final cover applied to areas of the landfill that have reached interim or final grade? | Yes |
| 7. | Does the landfill have a geosynthetic or clay liner? | Yes |
| 8. | In which bracket (I to V) does the LFG System Area Coverage Percentage fall? | II (60 - 80%) |

See users' guide for assistance in answering the above questions or for instructions on how to enter a user-specified or default collection efficiency below.

## Modeling Parameters

Based on your inputs, the model will use the "model recommended" values below to estimate the gas potential of the landfill. If you have reliable data that suggest a different value should be used, you may enter a different value to the right of the model recommended value and it will be used to generate the gas estimates.

| | Model Recommended Value | User Recommended Value |
|---|---|---|
| k (1/yr) | 0.18 | |
| $L_0$ ($m^3$/metric tonne) | 56 | 50 |
| Collection Efficiency | 60% | |
| Fire Discount Factor | None | **Cannot Be Changed** |

## Annual Landfill Activity Data

Input into column 2 the landfill's annual waste acceptance rate. The model recommended or user recommended collection efficiencies have been entered into column 4. You may change these if you have better data for any given year. If the landfill has a gas collection system in place and has measured actual gas recovery for given years, these data may be entered into column 5 (do not enter zeros).

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| **Year** | **Disposal Rate (metric tonnes/yr)** | **Waste-in-Place (metric tonnes)** | **LFG Collection System Efficiency** | **Actual Measured Recovery ($m^3$/hr)** |
| 1997 | 18,000 | 18,000 | 0% | |
| 1998 | 563,774 | 581,774 | 0% | |
| 1999 | 654,106 | 1,235,880 | 0% | |
| 2000 | 712,521 | 1,948,401 | 0% | |
| 2001 | 841,719 | 2,790,120 | 0% | |
| 2002 | 1,047,886 | 3,838,006 | 0% | |
| 2003 | 1,126,419 | 4,964,425 | 0% | |
| 2004 | 1,161,308 | 6,125,733 | 0% | |
| 2005 | 1,265,079 | 7,390,812 | 0% | |
| 2006 | 1,277,500 | 8,668,312 | 30% | |
| 2007 | 1,277,500 | 9,945,812 | 40% | |
| 2008 | 1,380,000 | 11,325,812 | 40% | |
| 2009 | 1,380,000 | 12,705,812 | 60% | |
| 2010 | 1,380,000 | 14,085,812 | 65% | |
| 2011 | 0 | 14,085,812 | 65% | |
| 2012 | 0 | 14,085,812 | 65% | |
| 2013 | 0 | 14,085,812 | 65% | |
| 2014 | 0 | 14,085,812 | 65% | |
| 2015 | 0 | 14,085,812 | 65% | |

View Output Table

View Output Graph

Return to Inputs Page

# Example Landfill, M2M Mexico Presentation
## Shenzhen City, Guangdong Province

| Year | Disposal Rate | Waste In-Place | LFG Generation Rate | | Collection System Efficiency | LFG Recovery from Existing and Planned System | | | Energy Output From Direct Use Project[a] | Energy Output From Electric Generation Project[b] |
|---|---|---|---|---|---|---|---|---|---|---|
| | metric tonnes/yr | metric tonnes | ($m^3$/min) | ($m^3$/hr) | (%) | ($m^3$/min) | ($m^3$/hr) | $MTCO_2e$ | (MJ/hr) | (MW) |
| 1997 | 18,000 | 18,000 | 0 | 0 | 0% | 0 | 0 | 0 | 0 | 0.000 |
| 1998 | 563,774 | 581,774 | 1 | 34 | 0% | 0 | 0 | 0 | 0 | 0.000 |
| 1999 | 654,106 | 1,235,880 | 18 | 1,098 | 0% | 0 | 0 | 0 | 0 | 0.000 |
| 2000 | 712,521 | 1,948,401 | 36 | 2,157 | 0% | 0 | 0 | 0 | 0 | 0.000 |
| 2001 | 841,719 | 2,790,120 | 53 | 3,153 | 0% | 0 | 0 | 0 | 0 | 0.000 |
| 2002 | 1,047,886 | 3,838,006 | 70 | 4,230 | 0% | 0 | 0 | 0 | 0 | 0.000 |
| 2003 | 1,126,419 | 4,964,425 | 92 | 5,520 | 0% | 0 | 0 | 0 | 0 | 0.000 |
| 2004 | 1,161,308 | 6,125,733 | 112 | 6,747 | 0% | 0 | 0 | 0 | 0 | 0.000 |
| 2005 | 1,265,079 | 7,390,812 | 131 | 7,838 | 0% | 0 | 0 | 0 | 0 | 0.000 |
| 2006 | 1,277,500 | 8,668,312 | 149 | 8,945 | 30% | 45 | 2,684 | 176,985 | 45,288 | 4.320 |
| 2007 | 1,277,500 | 9,945,812 | 165 | 9,894 | 40% | 66 | 3,958 | 261,013 | 66,790 | 6.372 |
| 2008 | 1,380,000 | 11,325,812 | 178 | 10,687 | 40% | 71 | 4,275 | 281,923 | 72,140 | 6.882 |
| 2009 | 1,380,000 | 12,705,812 | 192 | 11,543 | 60% | 115 | 6,926 | 456,772 | 116,882 | 11.151 |
| 2010 | 1,380,000 | 14,085,812 | 204 | 12,259 | 65% | 133 | 7,968 | 525,502 | 134,469 | 12.828 |
| 2011 | 0 | 14,085,812 | 214 | 12,856 | 65% | 139 | 8,357 | 551,115 | 141,023 | 13.454 |
| 2012 | 0 | 14,085,812 | 179 | 10,738 | 65% | 116 | 6,980 | 460,330 | 117,793 | 11.237 |
| 2013 | 0 | 14,085,812 | 149 | 8,970 | 65% | 97 | 5,830 | 384,500 | 98,389 | 9.386 |
| 2014 | 0 | 14,085,812 | 125 | 7,492 | 65% | 81 | 4,870 | 321,161 | 82,181 | 7.840 |
| 2015 | 0 | 14,085,812 | 104 | 6,258 | 65% | 68 | 4,068 | 268,257 | 68,643 | 6.549 |
| 2016 | 0 | 14,085,812 | 87 | 5,227 | 65% | 57 | 3,398 | 224,067 | 57,336 | 5.470 |
| 2017 | 0 | 14,085,812 | 73 | 4,366 | 65% | 47 | 2,838 | 187,156 | 47,891 | 4.569 |
| 2018 | 0 | 14,085,812 | 61 | 3,647 | 65% | 40 | 2,370 | 156,326 | 40,002 | 3.816 |
| 2019 | 0 | 14,085,812 | 51 | 3,046 | 65% | 33 | 1,980 | 130,574 | 33,412 | 3.188 |
| 2020 | 0 | 14,085,812 | 42 | 2,544 | 65% | 28 | 1,654 | 109,065 | 27,908 | 2.662 |
| 2021 | 0 | 14,085,812 | 35 | 2,125 | 65% | 23 | 1,381 | 91,099 | 23,311 | 2.224 |
| 2022 | 0 | 14,085,812 | 30 | 1,775 | 65% | 19 | 1,154 | 76,092 | 19,471 | 1.858 |
| 2023 | 0 | 14,085,812 | 25 | 1,483 | 65% | 16 | 964 | 63,557 | 16,264 | 1.552 |
| 2024 | 0 | 14,085,812 | 21 | 1,238 | 65% | 13 | 805 | 53,088 | 13,584 | 1.296 |
| 2025 | 0 | 14,085,812 | 17 | 1,034 | 65% | 11 | 672 | 44,343 | 11,347 | 1.082 |
| 2026 | 0 | 14,085,812 | 14 | 864 | 65% | 9 | 562 | 37,038 | 9,478 | 0.904 |
| 2027 | 0 | 14,085,812 | 12 | 722 | 65% | 8 | 469 | 30,937 | 7,916 | 0.755 |

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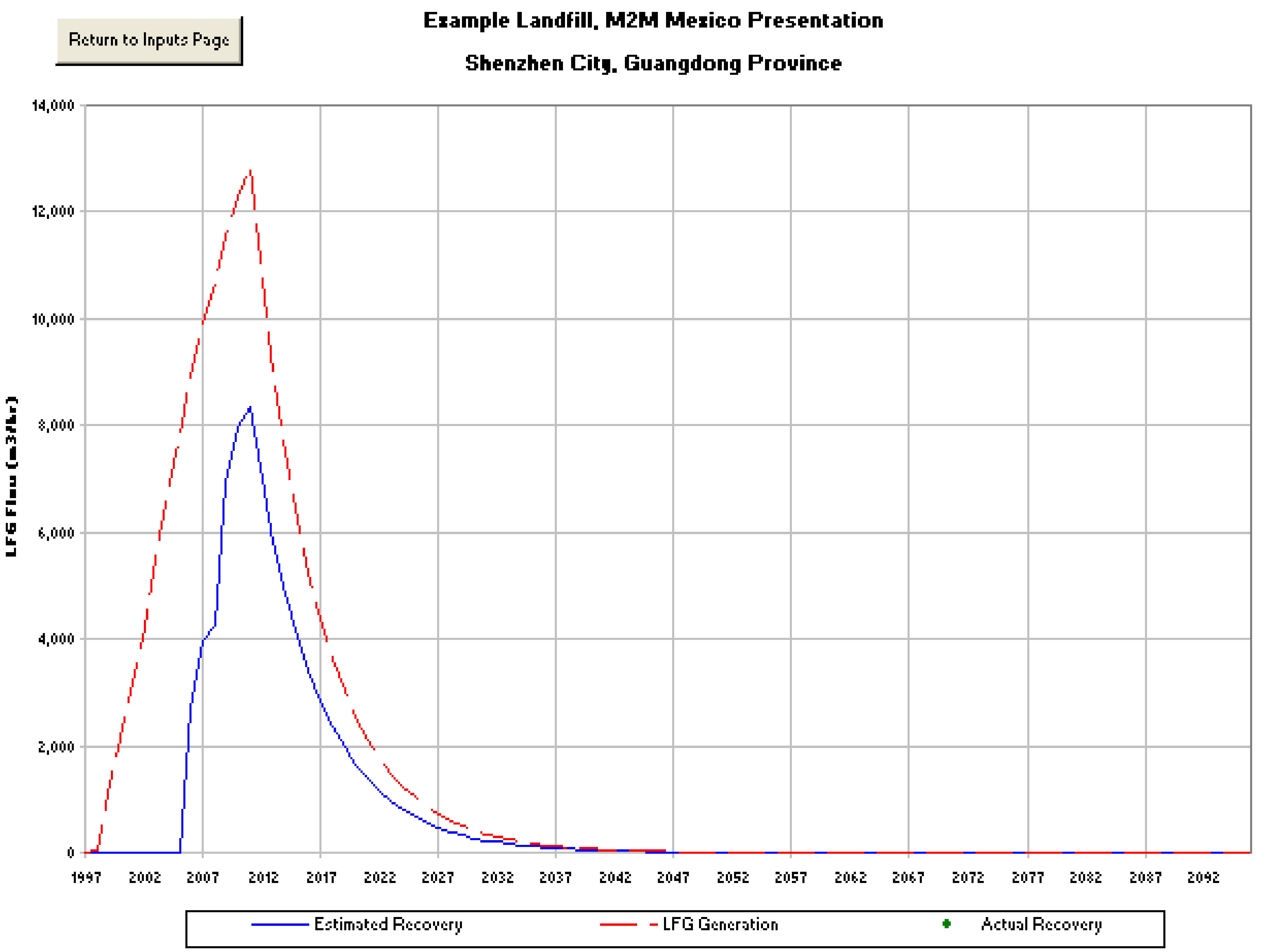

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# Recommended Future Modifications

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- Calibrate the model with additional actual site recovery data, esp. from landfills in the "Cold and Wet" zone
- Incorporate use of multiple k and $L_0$ to model different waste fractions at a given time
- Allow the use of different k and $L_0$ values for different years to reflect changes in waste composition over time

# Thank You

- Any questions?

- Email contact:
  bryce.lloyd@owthk.com.hk