Life-Cycle Inventory of Municipal Solid Waste Landfills

Remi Coulon
Ecobalance - PricewaterhouseCoopers

Outline

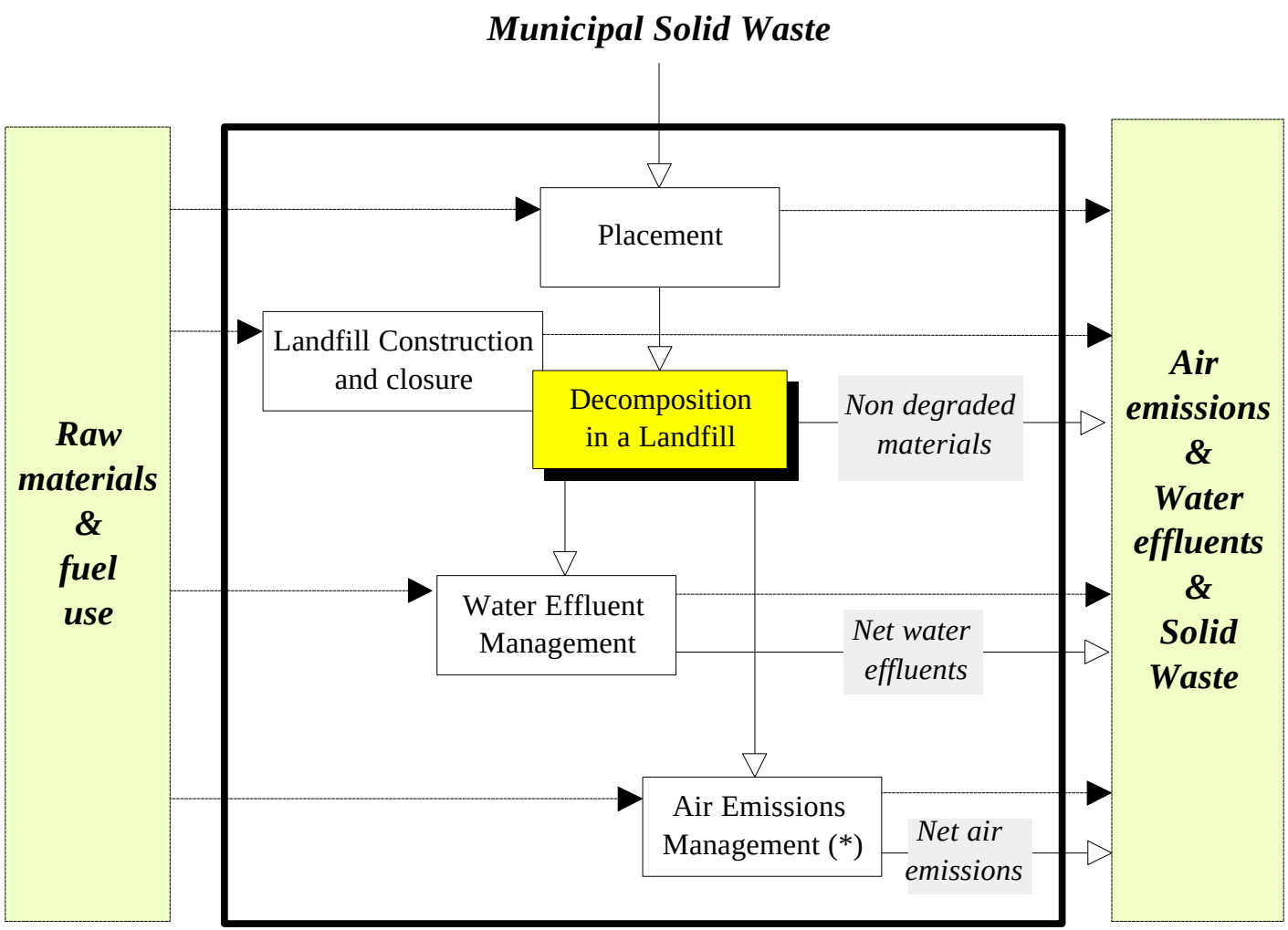
- Sponsors and partners
- Project goal
- Scoping overview
- Overview of the modeling
- Results

Sponsors and Partners

- **Sponsor: Environmental Industry Association Research and Education Foundation (EIA-REF)**
- **Partners:**
  - **Environmental Industry Association and its members (Waste Management, Inc. and others)**
  - **SITA and CGEA (France)**
  - **US EPA**
  - **Academia: Dr. Robert Ham and Dr. Morton Barlaz**
  - **Ecobalance Inc.**

Objectives of the Project

- **Evaluate energy requirements and environmental emissions from modern controlled landfills:**
  - **US: Subtitle 'D' regulation (40 CFR PART 258)**
  - **France: Class II landfills**
- **Provide a basis for subsequent comparisons with other waste management strategies**



(*) includes energy recovery from methane emissions and the subsequent economies of emissions

Inventory Flows Considered

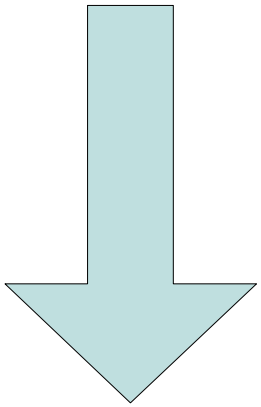
- **List of parameters considered:**

	water effluents only	*water effluents and air emissions*
- Net Energy	- BOD	- benzene
- CO_2 (fossil)	- COD	- chloroform
- CO_2 (biomass)	- TSS	- carbon tetrachloride
- CO	- NH_3	- ethylene dichloride
- NOx	- PO_4	- methylene chloride
- SOx	- arsenic	- trichloroethylene
- PM_{10}	- barium	- perchloroethylene
- Total Particulate	- cadmium	- vinyl chloride
- Methane	- chromium	- toluene
	- lead	- xylenes
	- mercury	- ethylbenzene
	- selenium	- NMOC
	- silver	

Temporal Boundary

- **Wide array of possible time horizons**

Waste Placement



Infinite Time

- 15 Years
- for 50 years after closure
- 100 years (human lifetime)
- to end of methanogenic phase
- to end of period of “control”
- to end of predictable reactions
- until emissions ≤ “acceptable” levels
- until emissions ≤ background level
- 1 million years
- until all inputs become outputs

➡ **Selection of three horizons: 20 yr., 100 yr. and 500 yr.**

Data Collection - QA/QC

- **Initial screening questionnaire sent to over 100 landfills internationally. Screening criteria:**
  - **75% or more MSW**
  - **Leachate and gas data: frequent sampling and data for a long period of time**
- **37 detailed questionnaires analyzed by the Technical Committee:**
  - **13 from US. Sites**
  - **24 from French and UK Sites**

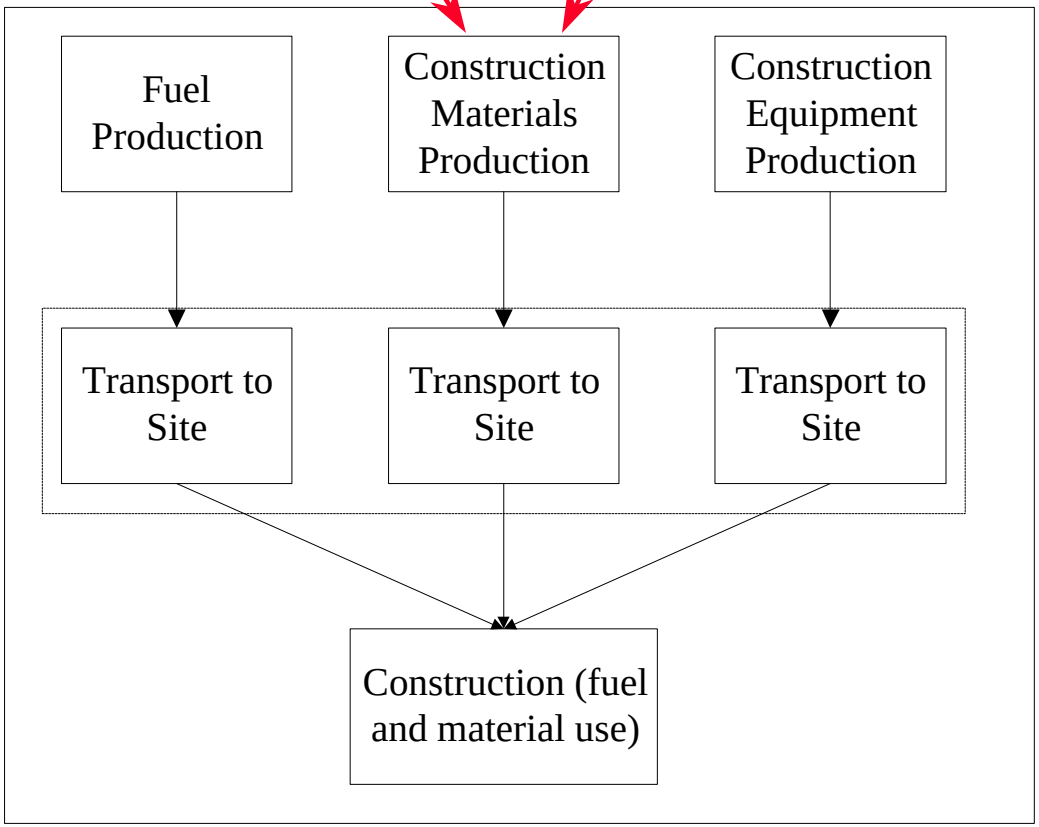
Modeling

- Construction
- Operations
- Closure
- Post-closure
- Landfill gas
- Leachate

Construction: Overview

Liner: Clay, Sand, HDPE, Geotextile

Others: HDPE, PVC, Steel, Concrete, Asphalt

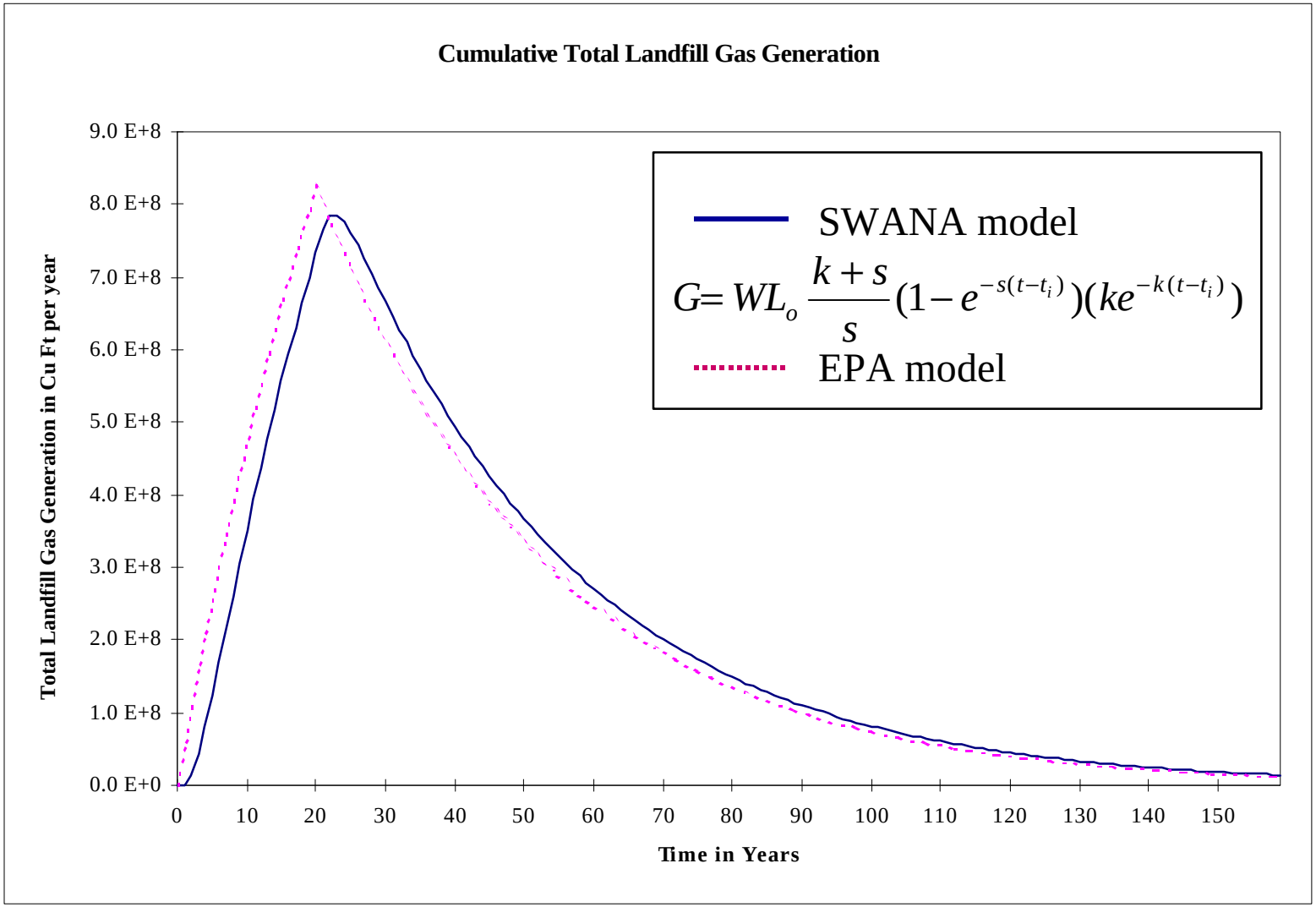


Construction: Summary

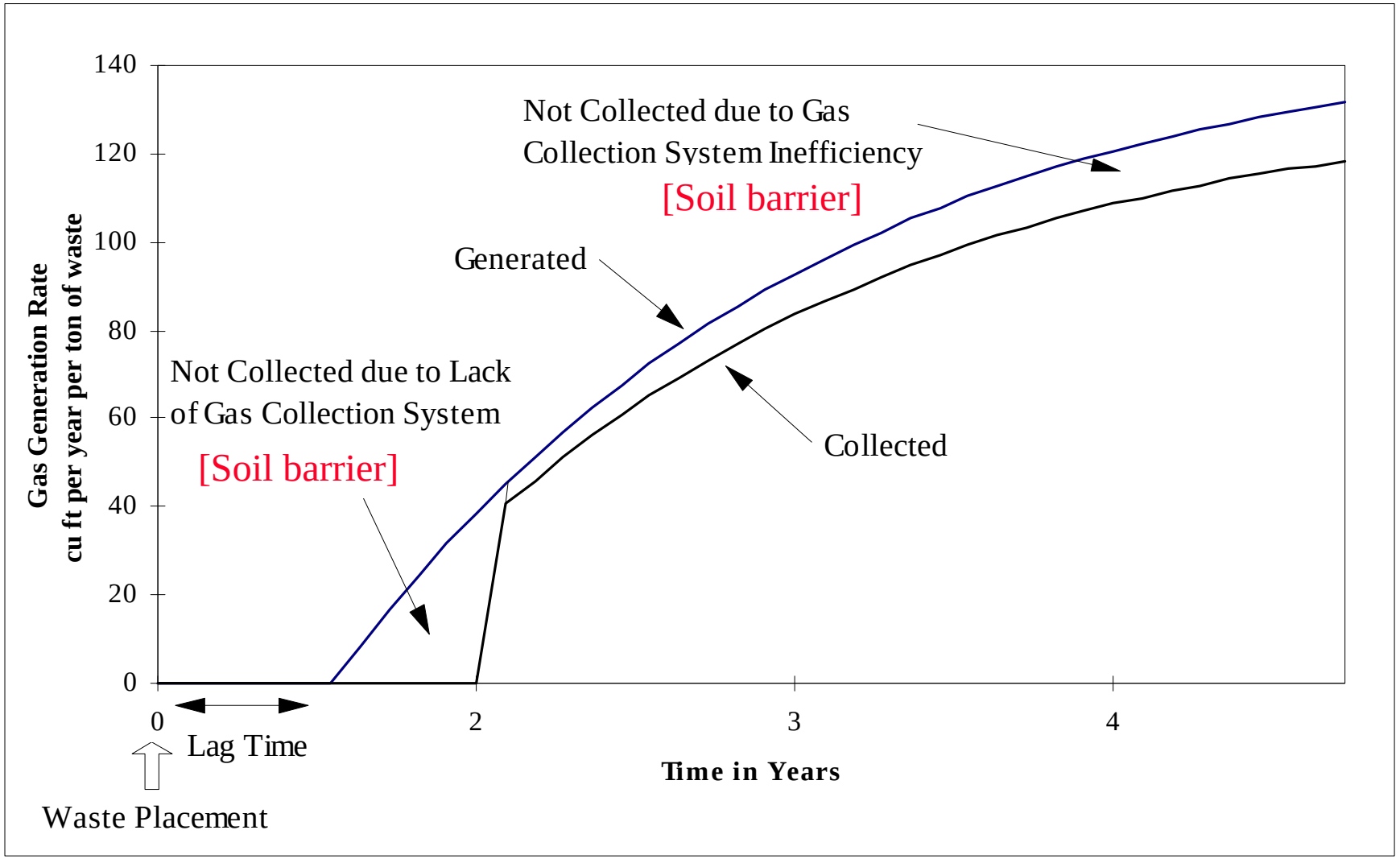
Material	*Distance Transported (kilometers)*	*Amount of Material Used (kg/tonne of waste)*	*Percent of Total Amount Transported (percent)*	*Weighted Average Haul Distance (kilometers)*
Clay	8	66	70 %	5.6
Sand	32	28	30 %	9.6
Total:		**94**	**100 %**	**15**

Material	*Distance Transported (kilometers)*	*Amount of Material Used (kg/tonne of waste)*	*Percent of Total Amount Transported (percent)*	*Weighted Average Haul Distance (kilometers)*
Fuel	80	0.19	38%	31
HDPE (used in liner)	402	0.085	18%	71
Geotextiles	402	0.017	3.5%	14
HDPE (other than liner)	402	0.0026	0.54%	2.2
PVC	402	0.0020	0.42%	1.7
Steel	402	0.016	3.3%	13
Concrete	80	0.09	19%	15
Asphalt	80	0.085	18%	14
Total:		**0.49**	**100%**	**162**

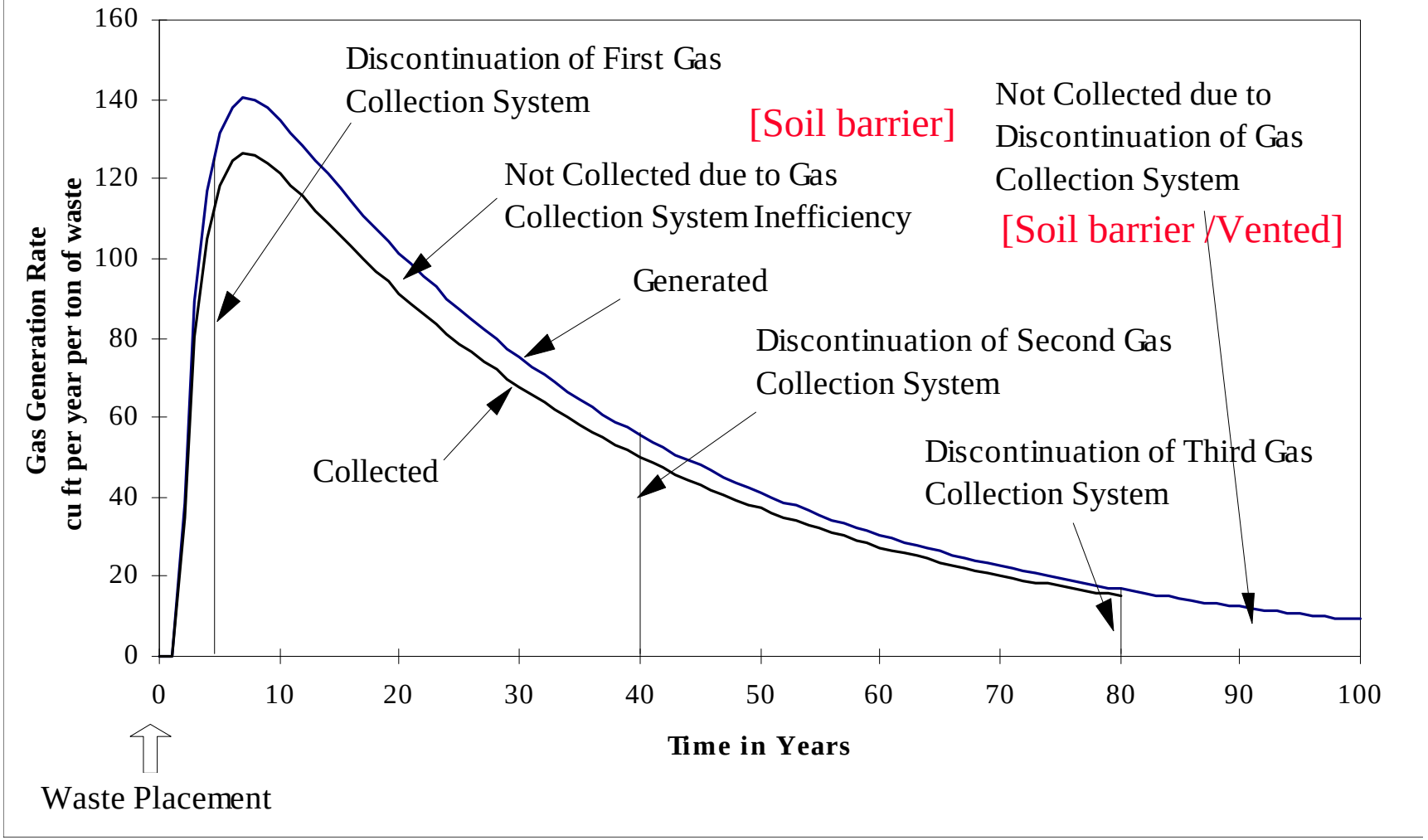
Landfill Gas: Production



Landfill Gas Treatment: Overview (1/2)



Landfill Gas Treatment: Overview (2/2)



Landfill Gas Treatment: Beneficial Uses

- **Three options considered:**
  - **Turbine**
  - **Steam production**
  - **Internal combustion engines**
- **For each option:**
  - **Modeling of the destruction efficiencies (mostly AP-42)**
  - **Modeling of the emissions**
  - **Modeling of the energy credit**
  - **Subtraction of an equivalent electricity production from the <u>average US grid</u>** [electricity produced from landfill gas is considered part of the base electricity generation grid]

Leachate Quantity (1/3)

- **Necessity to account for the life of a typical cell:**
  - **Influence of precipitation**
  - **Influence of moisture in the waste**
- **Analysis of the questionnaires' values: 4 categories of sites**
  - **Cells without final cover**
  - **Cells mostly covered with intermediate cover or final cover (but no more than 40% final cover)**
  - **Cells with more than 40% final cover**
  - **Cells with 100% final cover**

Leachate Quantity (2/3)

- **Type of cover for an average ton of waste in an average landfill**

Years Since First Waste Placement	*Percent of Landfill Covered With: Daily Cover*	*Intermediate Cover*	*Final Cover*	*Total*
0.5	100%	0%	0%	100%
1	50%	50%	0%	100%
1.5	0%	100%	0%	100%
2	0%	94%	6%	100%
2.5	0%	88%	12%	100%
3	0%	82%	18%	100%
3.5	0%	76%	24%	100%
4	0%	71%	29%	100%
4.5	0%	65%	35%	100%
5	0%	59%	41%	100%
5.5	0%	53%	47%	100%
6	0%	47%	53%	100%
6.5	0%	41%	59%	100%
7	0%	35%	65%	100%
7.5	0%	29%	71%	100%
8	0%	24%	76%	100%
8.5	0%	18%	82%	100%
9	0%	12%	88%	100%
9.5	0%	6%	94%	100%
10	0%	0%	100%	100%

Leachate as a % of precipitation

20%

6.6%

6.5%

0.2%

Leachate Quantity: Summary (3/3)

- **For an average US modern landfill:**
  - **Yearly precipitation: 89 cm/year**
  - **Amount of refuse per area of landfill surface: 202,406 tonne/hectare**

Time Since Waste Placement (years)	*Leachate Generated [liter/tonne]*
20	37
100	44
500	79

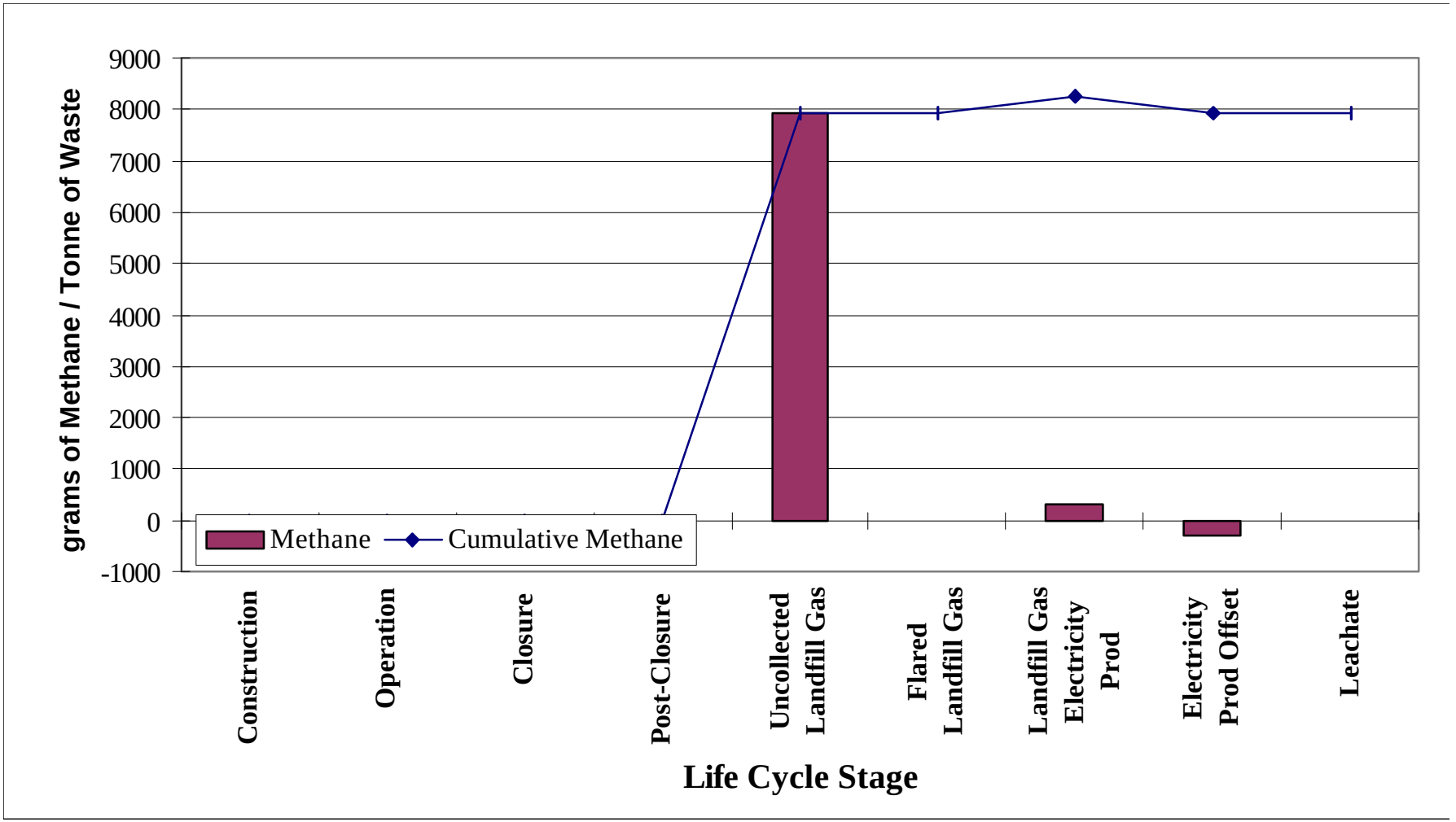
Leachate Quality

- **BOD/COD**
  - BOD modeled based on theoretical concentration and decrease over time
  - COD modeled as a BOD/COD ratio
- **Other water effluents (metals, trace organics, TSS, NH_3, PO_4):**
  - Assumed to be constant over time
  - Use of the questionnaires' data
- **Dealing with non-detected values: set of end-points**
  - Low: median of detected values and $^1/_2$ of reporting limit for non-detected values
  - High: median of detected values only

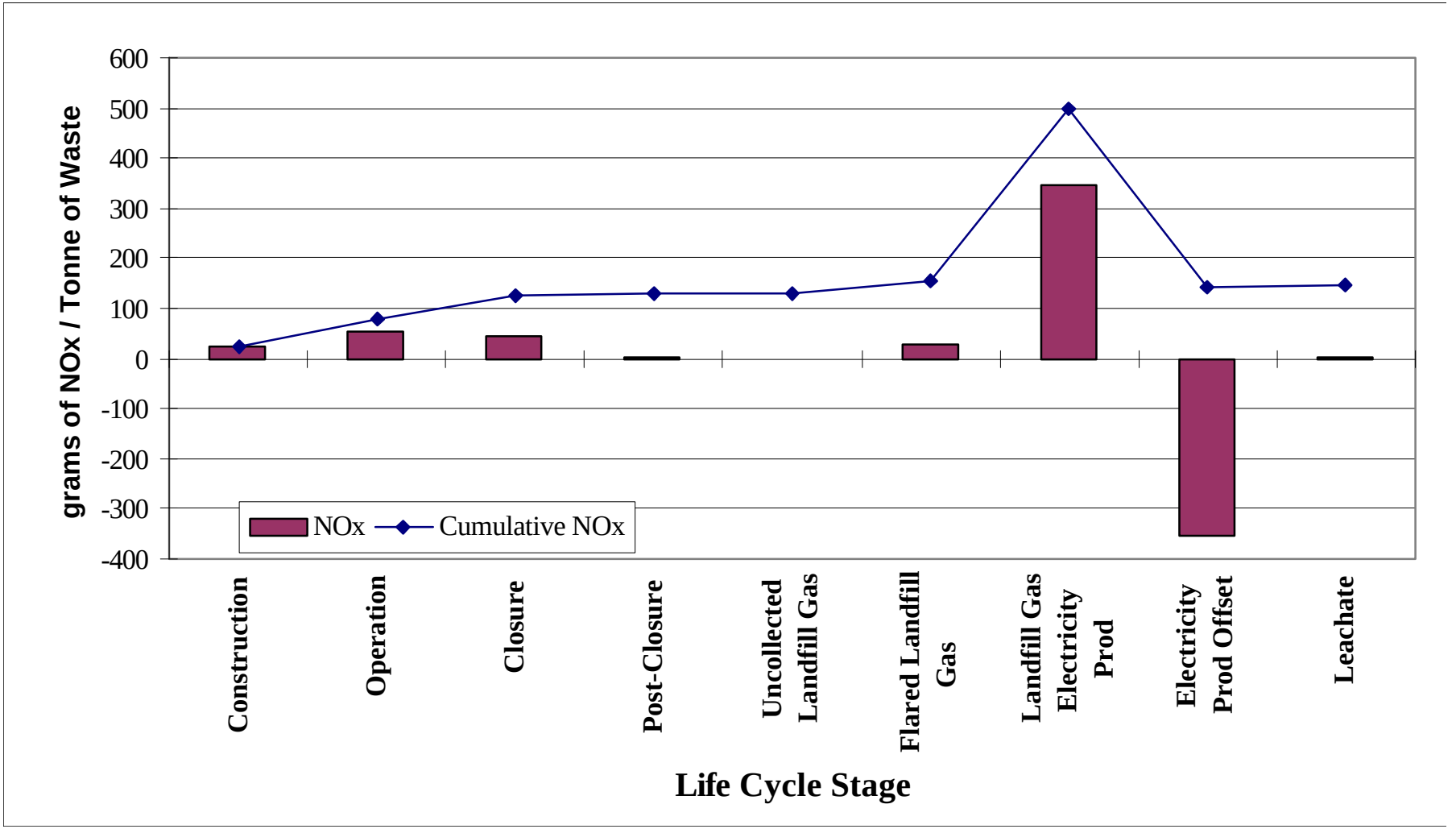
Leachate Treatment

- Leachate collection efficiency: 99.8% (0.2% released as is)
- Transport of leachate to a Publicly Owned Treatment Works (POTW)
- Treatment in a POTW (removal efficiencies)

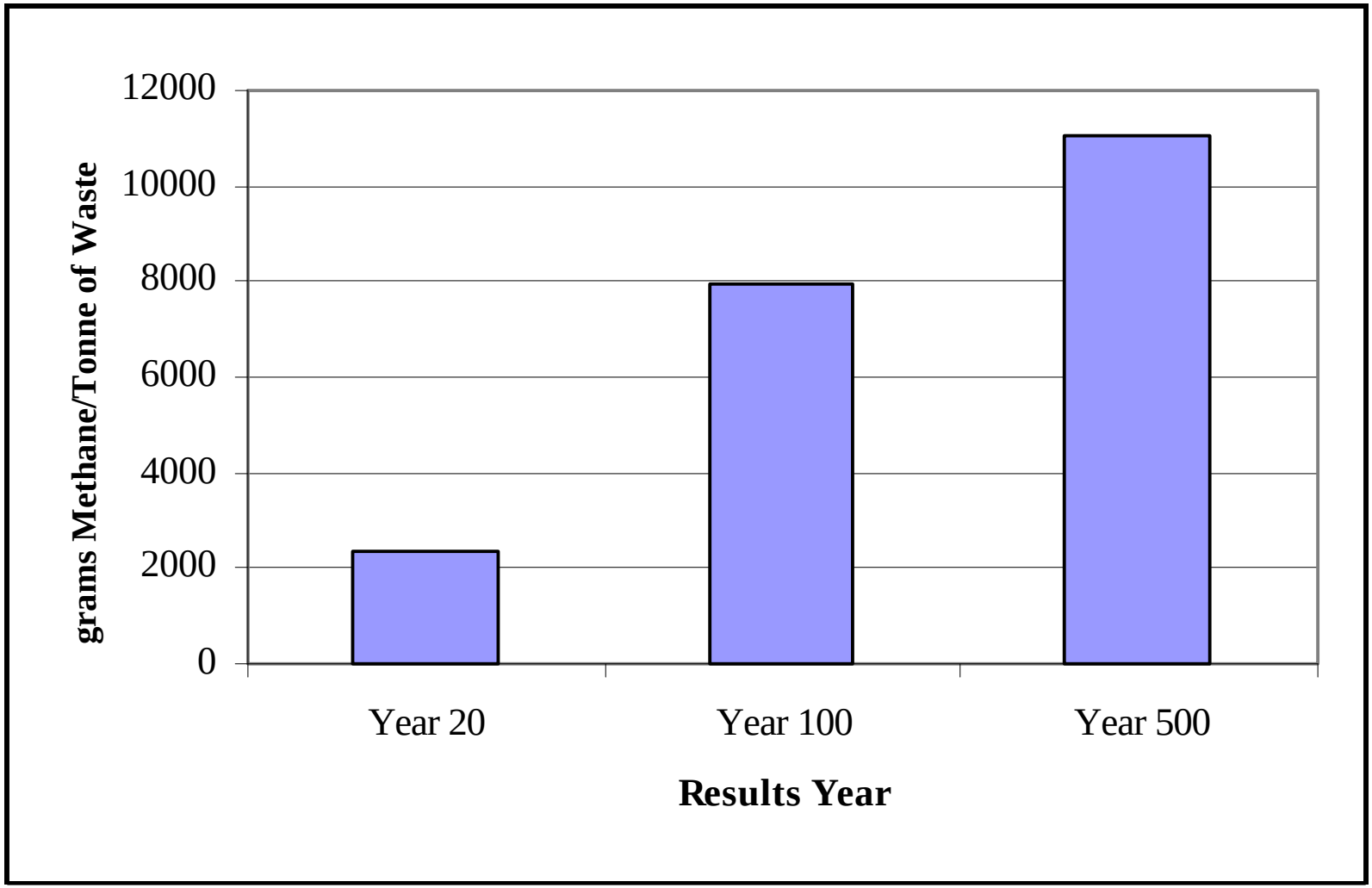
Baseline Results (1/2)



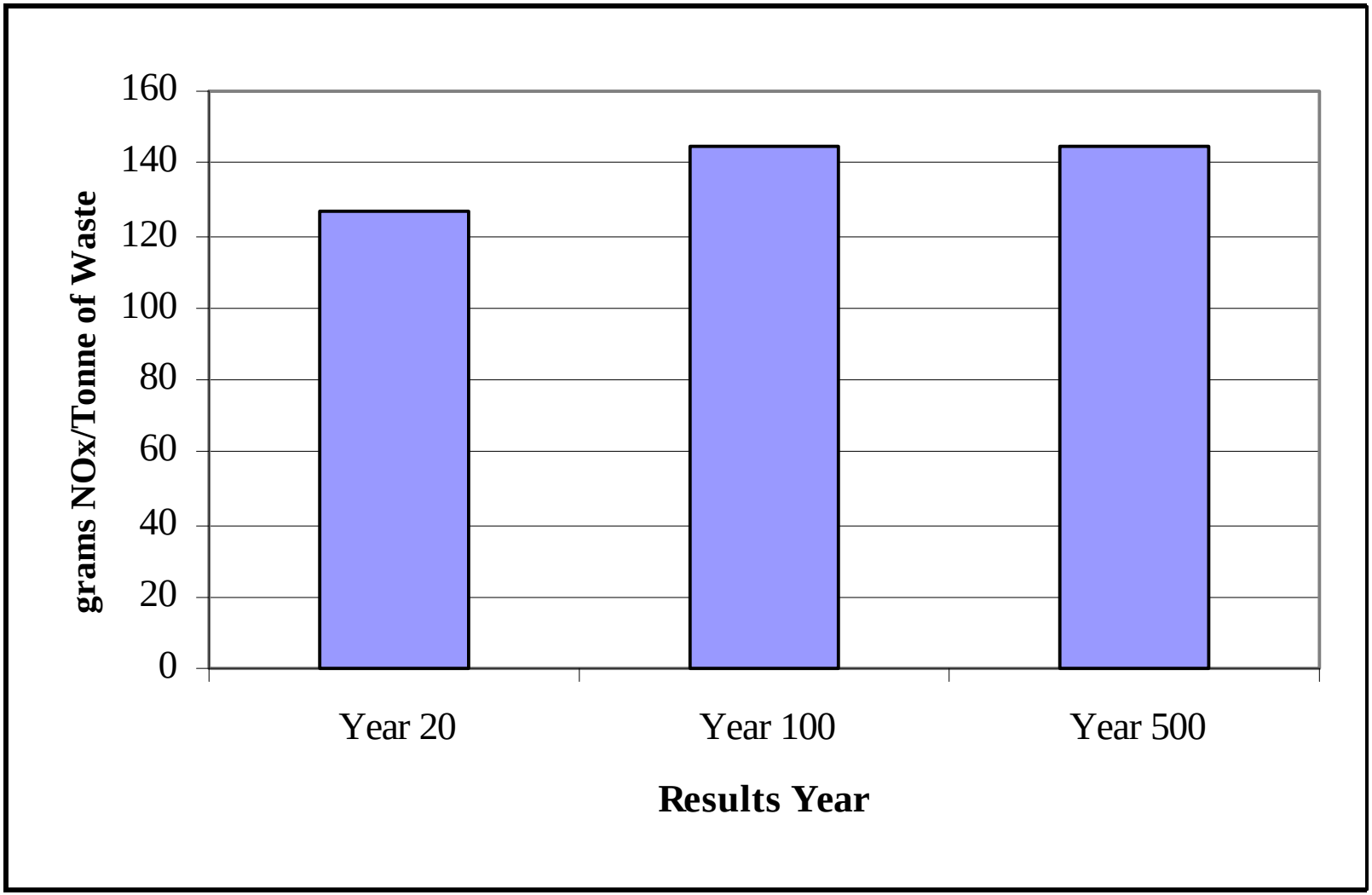
Baseline Results (2/2)



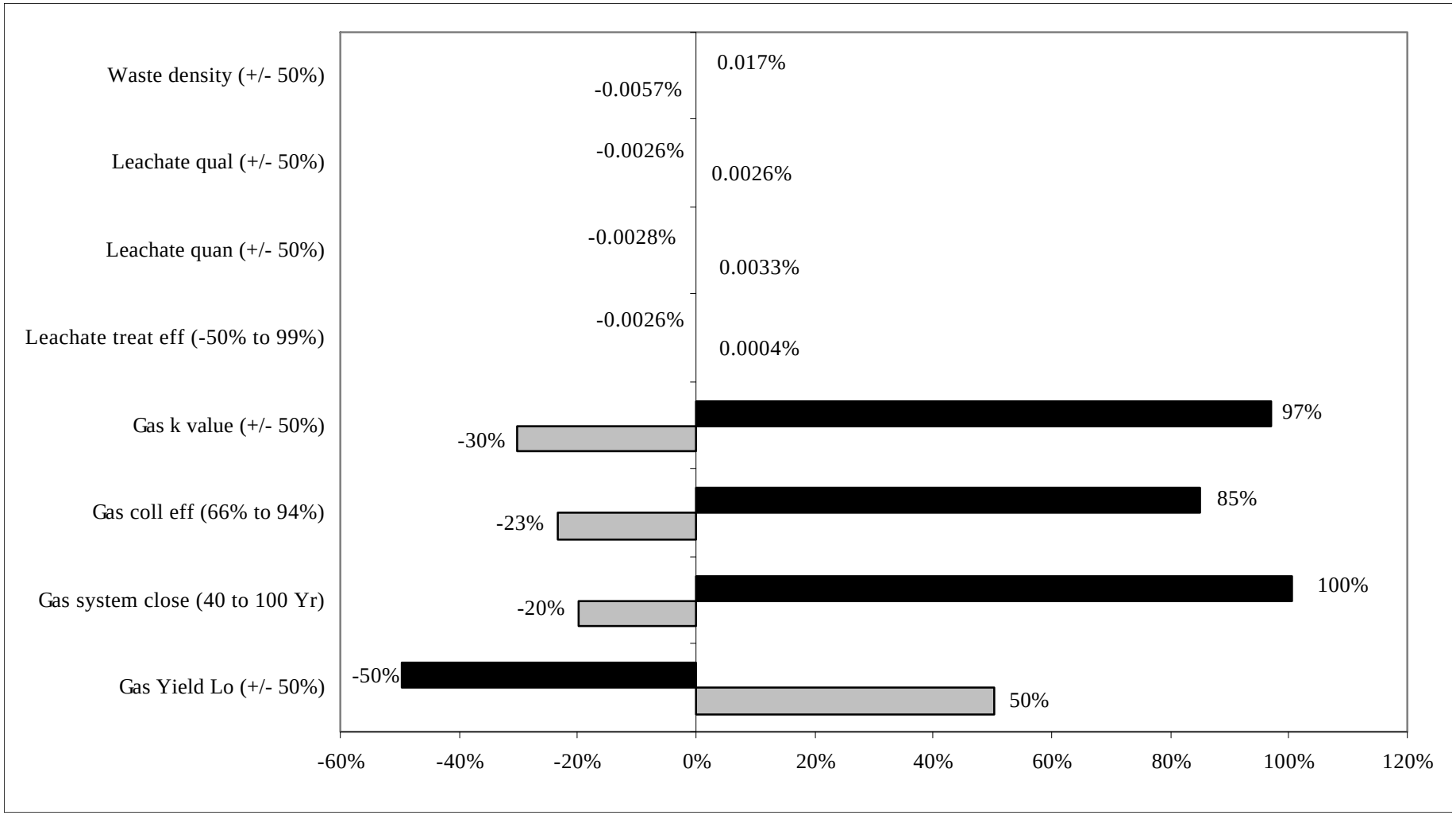
Results Over Time (1/2)



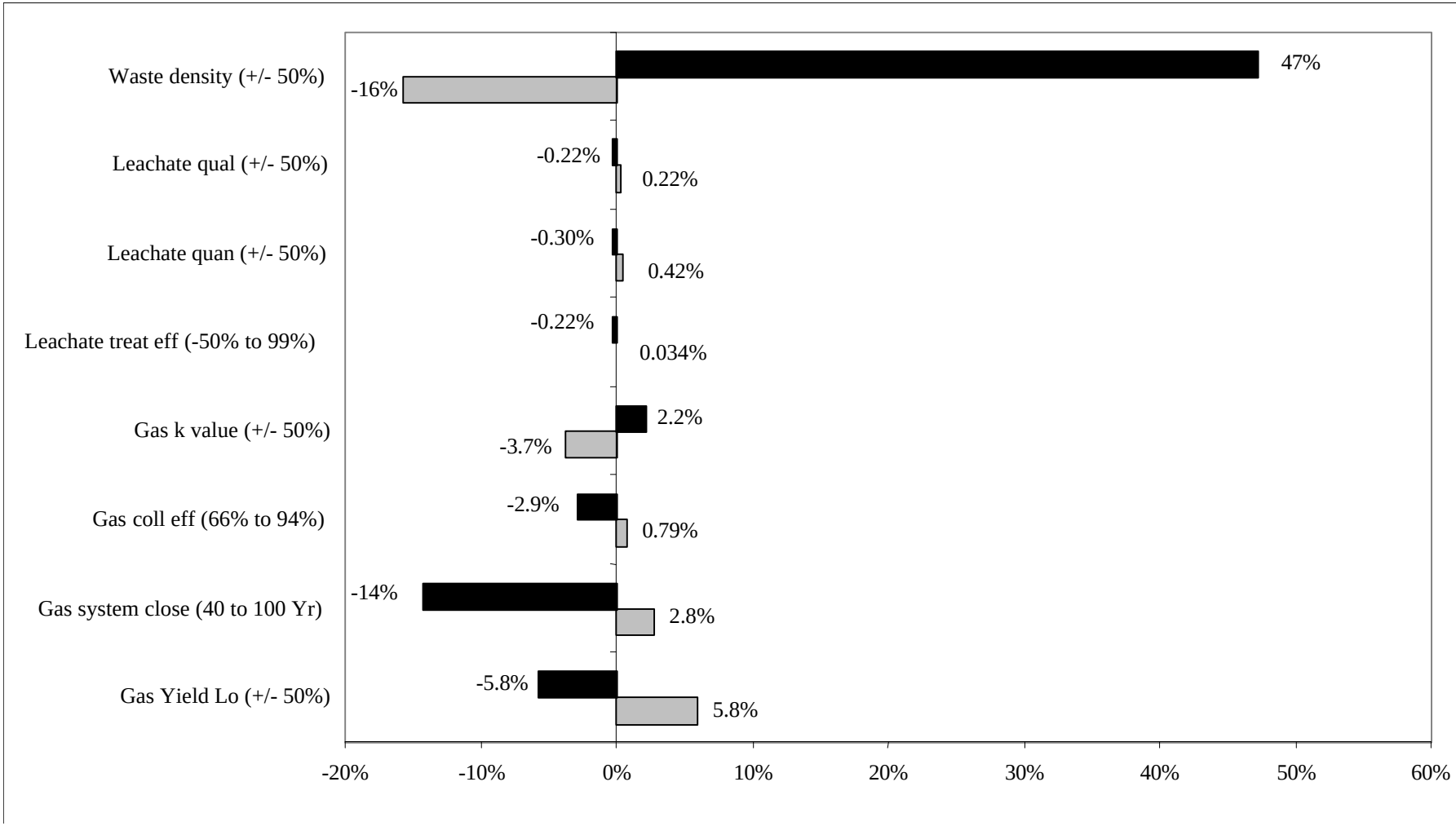
Results Over Time (2/2)



Methane Sensitivity Analysis



NOx Sensitivity Analysis



Conclusions

- Comprehensive landfill model and software
- Used in other waste management tools to represent modern landfills
- Allocation is done to characterize emissions per specific waste component
- Case studies are being performed to test the use of the model and compare landfilling to other waste management options