

*turning knowledge into practice*

# **Analysis of Municipal Solid Waste Management Systems for Bank Member Countries**

**Keith Weitz and Alexandra Zapata**

**World Bank Urban Week  
March 12, 2009**



*RTI International is a trade name of Research Triangle Institute*

3040 Cornwallis Road  
Phone 919-541-6000

■ P.O. Box 12194

■ Research Triangle Park, North Carolina, USA 27709

e-mail [kaw@rti.org](mailto:kaw@rti.org); [azapata@rti.org](mailto:azapata@rti.org)

1

# Presentation Outline

- Study background and objectives
- Study design
- Comparison of study site characteristics
- Key findings
- Uncertainties and Limitations



# Study Background

- Study was funded through the Japanese Trust Fund. RTI subcontracted by Nippon Koei to run RTI's Municipal Solid Waste Decision Support Tool.
- Goal: Provide guidance for solid waste management planning in developing countries.
  - Identify key waste generation and economic characteristics defining the selection of waste recycling and treatment processes and the magnitude of their cost and environmental benefits.
  - Analyze different arrangements of technical systems, and also included scenarios that optimized energy, global warming emission reduction, and global dimming emission reduction.
  - Assess the extent to which results could be extrapolated to regions of the world with similar socio-economic characteristics.

# Study Approach

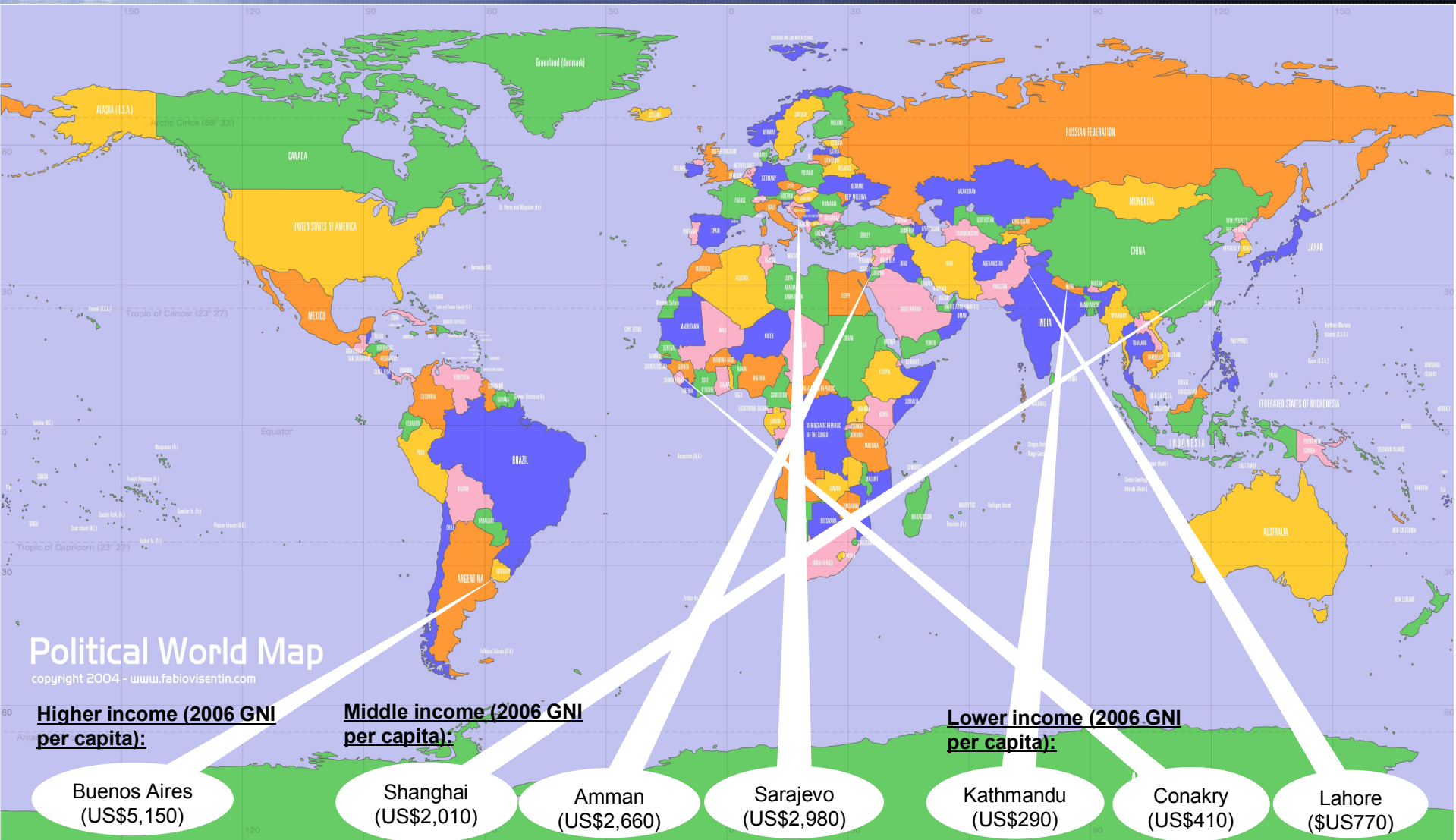
- Defined goals and scenarios to model
- Identified study cities
- Collected data
  - Waste characteristics
  - Existing waste management infrastructure
  - Energy and materials markets
  - Costs
- Inputted data into MSW DST and built tailored models for each city and run scenarios
- Compiled and evaluated results



# Brief Background on the Model Used

- RTI's Municipal Solid Waste Decision Support Tool (MSW DST) was used to analyze waste management scenarios
  - Applies principles of Full Cost Accounting and Life Cycle Assessment.
  - Contains North American default data that can be overwritten using site-specific data.
  - Can run simulation and optimization scenarios.
- Waste management technologies analyzed:
  - Recycling
  - Composting (organics)
  - Waste-to-Energy and incineration
  - Landfill disposal

# Study Cities

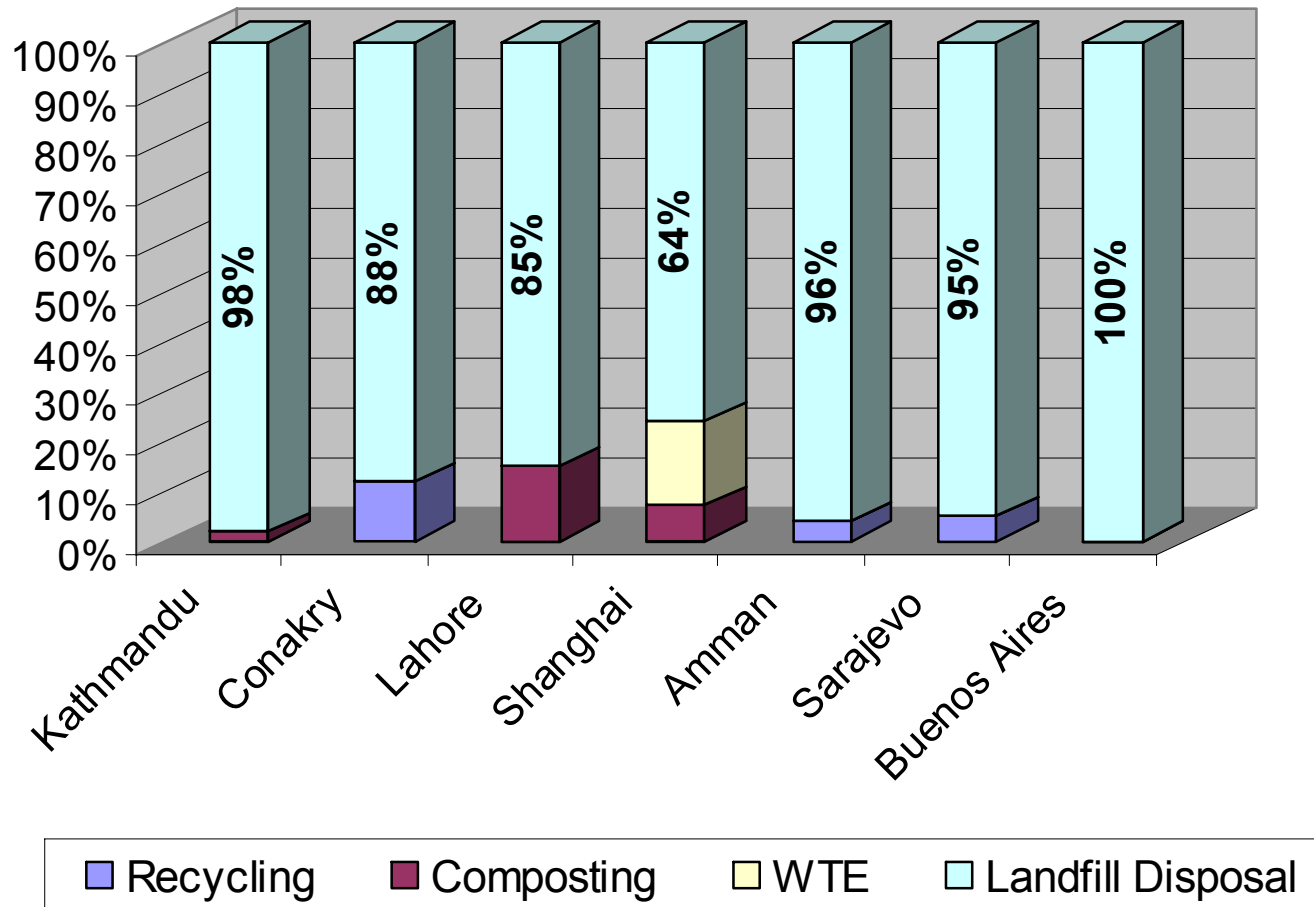


Political World Map  
copyright 2004 - www.fabiovisentin.com

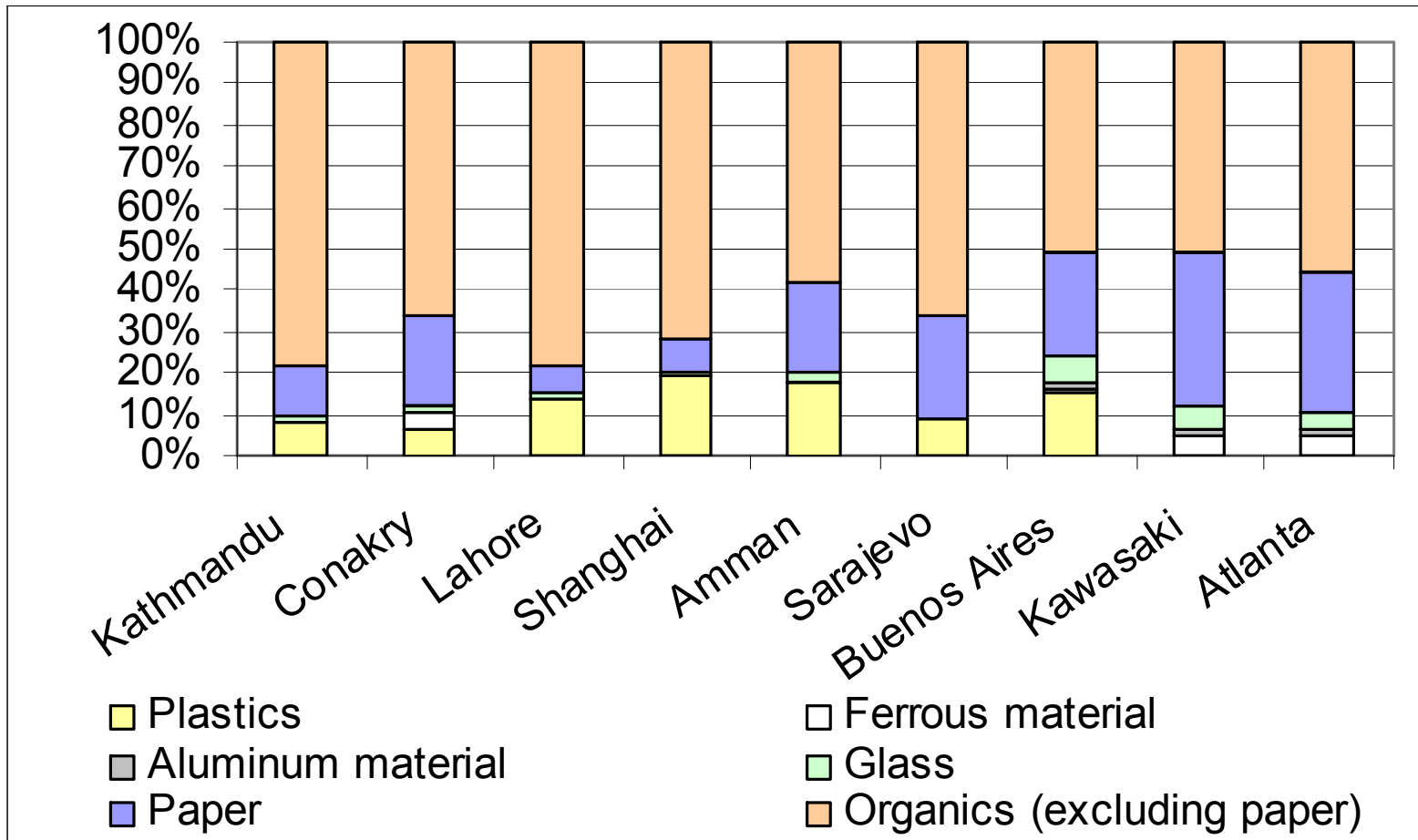
# Socio-Economic Information

City, Country, Region	Country GDP, \$ millions, 2006 <sup>*1</sup>	Country Population, Billions, 2006 <sup>*1</sup>	%Urban Population in Country, 2004 <sup>*2</sup>	GNI, \$ per capita, 2006	%Below Poverty Level, below \$1 a day <sup>*1</sup>	%Literacy, ages 15 and older, 2000-05 <sup>*1</sup>	Average Life Expectancy, 2005 <sup>*1</sup>	
							Male	Female
Buenos Aires, Argentina	214,058	39	90	5,150	6.6 (2004)	97	71	79
Conakry, Guinea	3,317	9	36	410	--	29	54	54
Shanghai, China	2,668,071	1,312	40	2,010	9.9 (2004)	91	70	74
Kathmandu, Nepal	8,052	28	15	290	24.1 (2003-04)	49	62	63
Lahore, Pakistan	128,830	159	34	770	17.0 (1998-99)	50	64	65
Amman, Jordan	14,176	6	79	2,660	<2.0 (2002-03)	91	71	74
Sarajevo, Bosnia and Herzegovina	11,296	4	45	2,980	--	97	72	77
Kawasaki, Japan	4,340,133	128	66	38,410	--	--	79	86
Atlanta, United States	13,201,819	299	80	44,970	--	--	75	81

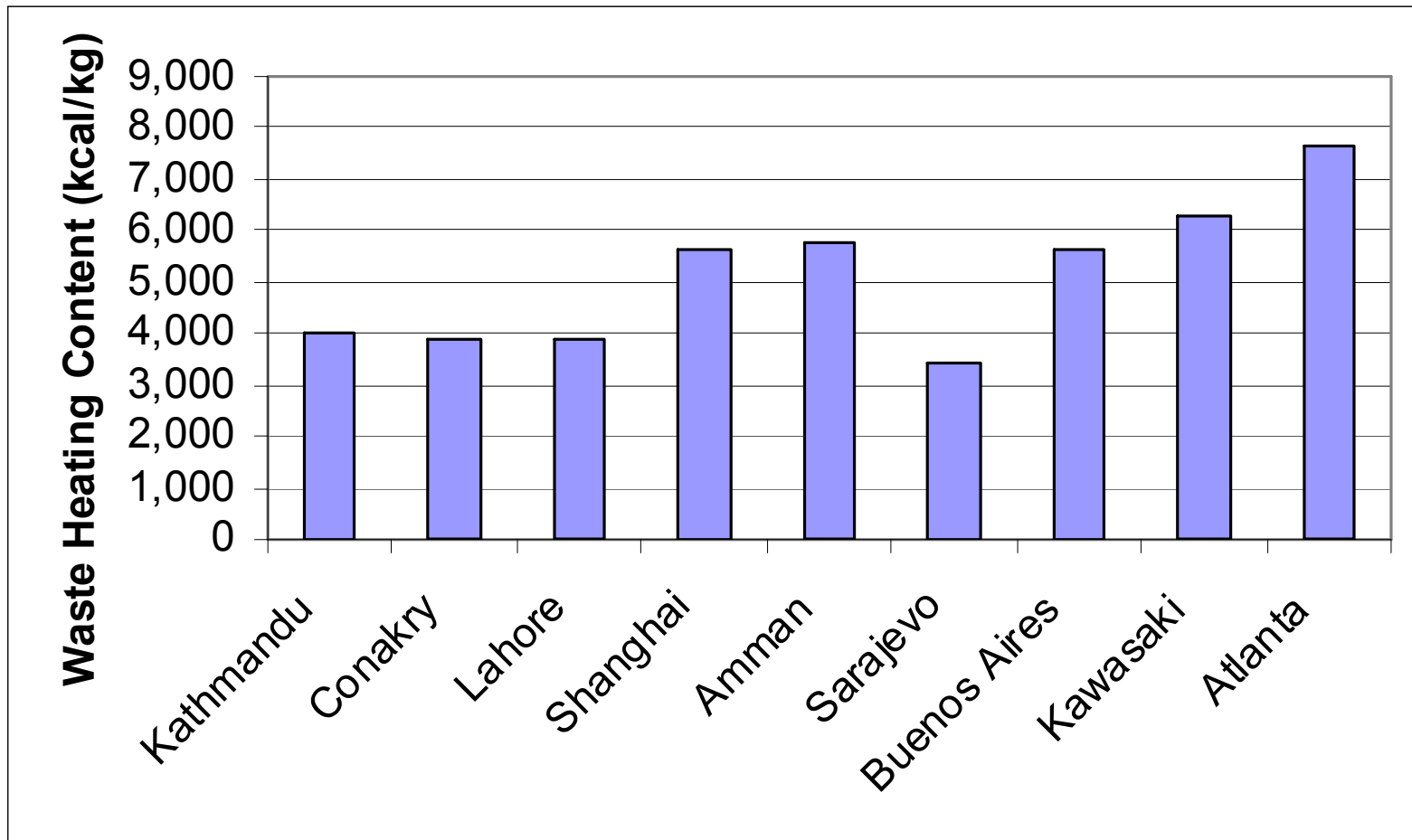
# Existing Waste Management Systems



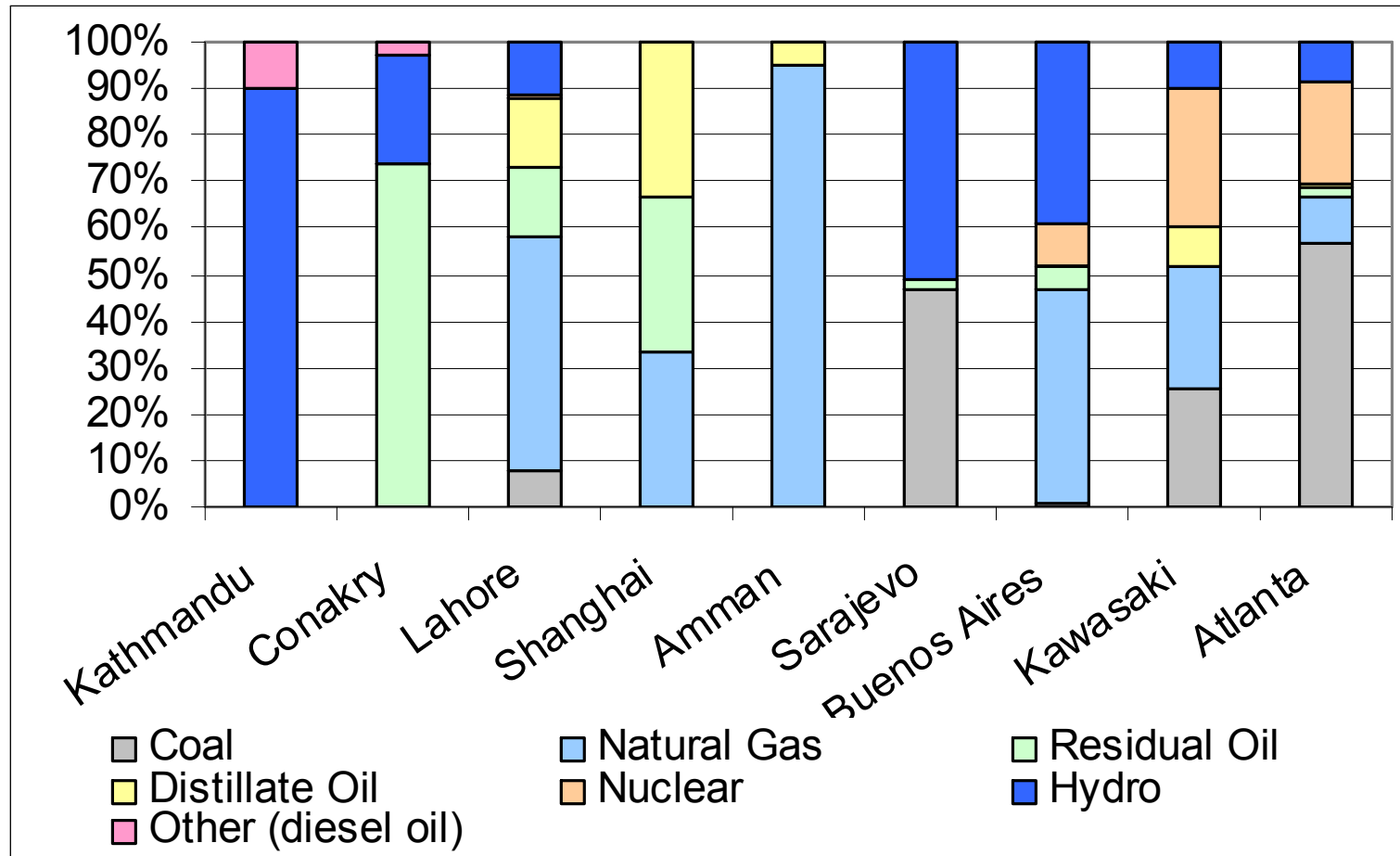
# Waste Composition



# Waste Characteristics – Btu Value



# Electricity Grid Mix of Fuels



# Waste Management Scenarios Analyzed

## Simulation Scenarios:

- **Group 1** includes base case simulation scenarios consist of 2 scenarios, one sending all the waste to an open dump and the other open burning.
- **Group 2** includes nine different scenarios, each sending all the waste to one primary technology/waste management process.

## Optimization Scenarios:

- **Group 3** optimization scenarios are set to maximize the amount of material recovered (or diverted from landfill disposal) using non-incineration processes.
- **Group 4** consists of maximizing the energy recovered.
- **Group 5** seeks to minimize climate change related emissions including carbon (global warming) and PM (global dimming) emissions.

# Cost Findings

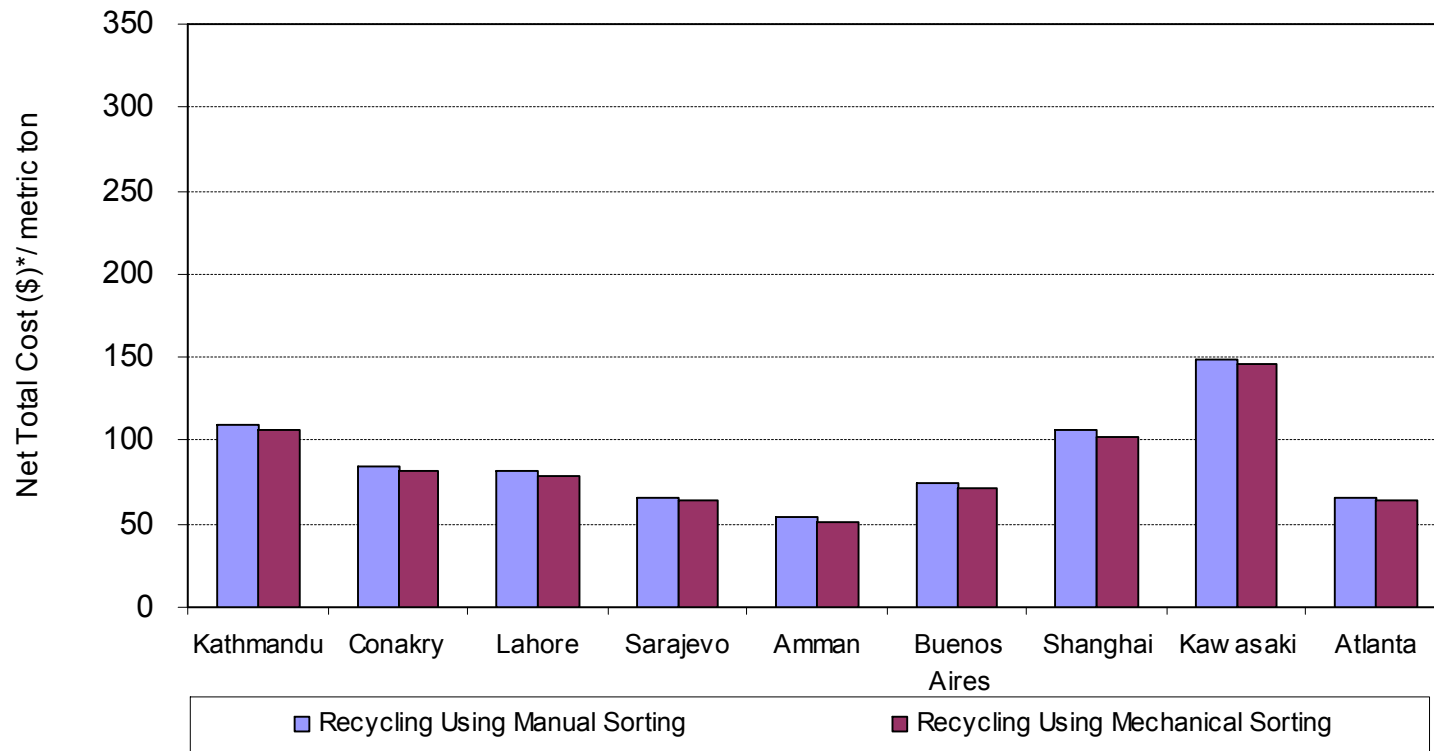
- Lowest cost process: landfill disposal
  - Land price can significantly impact landfill cost.
  - Breakpoints were not estimated.
- Highest cost process: incineration without energy recovery.
- Capital, labor and energy costs are key in determining cost tradeoffs between manual and mechanical operations.
  - Composting manual operations are more cost-effective than mechanical operations since those do not require any equipment, and labor (on a per ton basis) is cheaper than energy in most cities.
  - Manual MRF operations are less cost effective than mechanical MRF operations due to manual operations being very labor intensive and still needing equipment.

# Cost Findings (cont.)

- Potential cost savings associated with materials and energy recovery are large and can significantly reduce the total cost of waste management.
  - Revenues from the sale of recyclables ranged from US\$66-197 per metric ton of recyclables.
  - Revenues from the sale of electrical energy, in the case of incineration with energy recovery, ranged from US\$3- 59 per metric ton of waste incinerated.
  - Recovery rates and markets for recyclables cause significant variation in recycling costs among cities.



# Cost Findings Example: Recycling + Landfill Disposal of Residuals



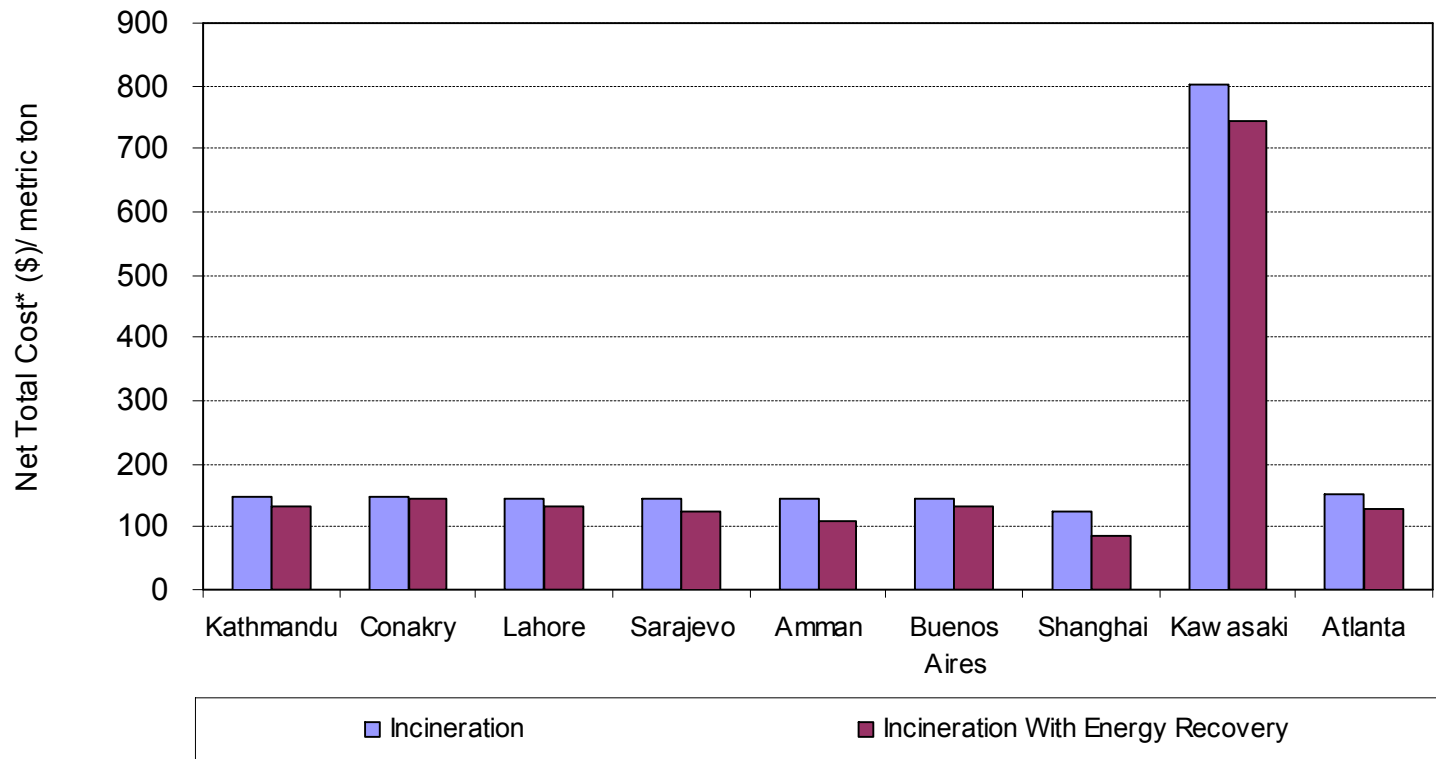
\*Results assuming zero price for landfill related land cost.

# Impact of Key Parameters on Net Recycling Cost

- ↓ Recyclables prices
- ↓ Percent of high-priced recyclables
- ↑ Percent of residual waste
- ↑ Energy (electricity and fuels) cost
- ↑ Labor cost



# Cost Findings Example: Incineration + Landfill Disposal of Residuals



\*Results assuming zero price for landfill related land cost.

# Impact of Key Parameters on Net Incineration Cost

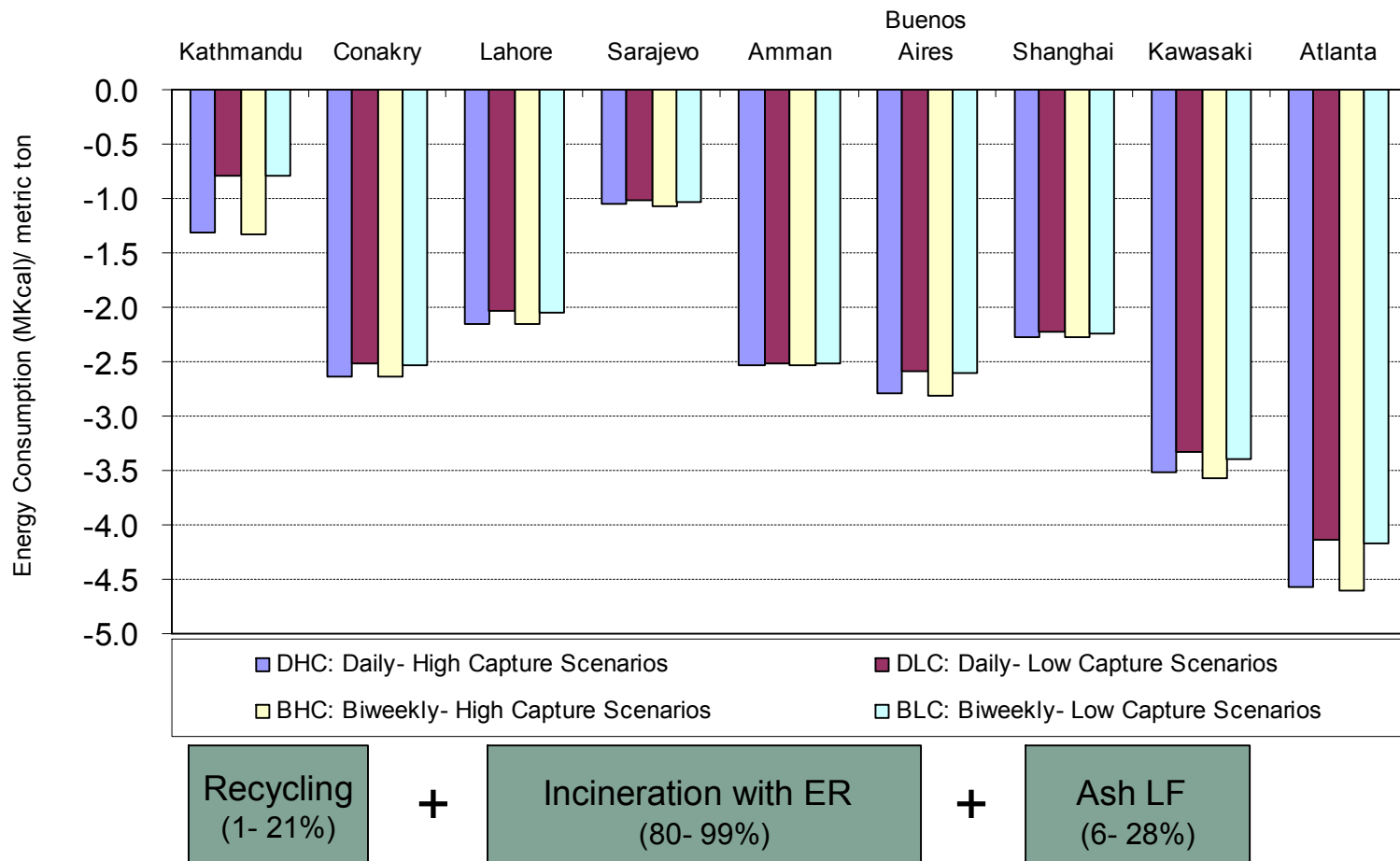
- ↓ Electricity prices
- ↓ Percent of high heating value waste
- ↑ Capital and O&M cost



# Energy Findings

- The most effective strategies for optimizing energy consumption included materials and energy recovery.
- Recyclables composition and quantity are key in determining energy savings.
  - Metals recycling, for example, results in significant benefits due to energy intensive nature of its production.
- Energy recovery via incineration depends on the composition and characteristics (e.g., heating value) of the MSW
  - For many of the Bank member cities the MSW stream generally has a low average heating value/ton value due to high levels of food waste and other wet organics waste, as well as inerts (ash and soil) in some cases.
- Energy offsets are directly dependent on the electricity grid mix used for each city.
  - Cities with a high percentage of hydroelectricity will have lower energy offsets.

# Energy Findings Example: Optimization of Energy Recovery



# Impact of Key Parameters on Net Energy

- ↓ Waste heating content
- ↓ Percent recyclables (metals)
- ↓ Percent fossil sources in electricity grid mix
- ↑ Percent non-fossil source in electricity grid mix
- ↑ Energy (electricity and fuels) consumed

# Emission Findings

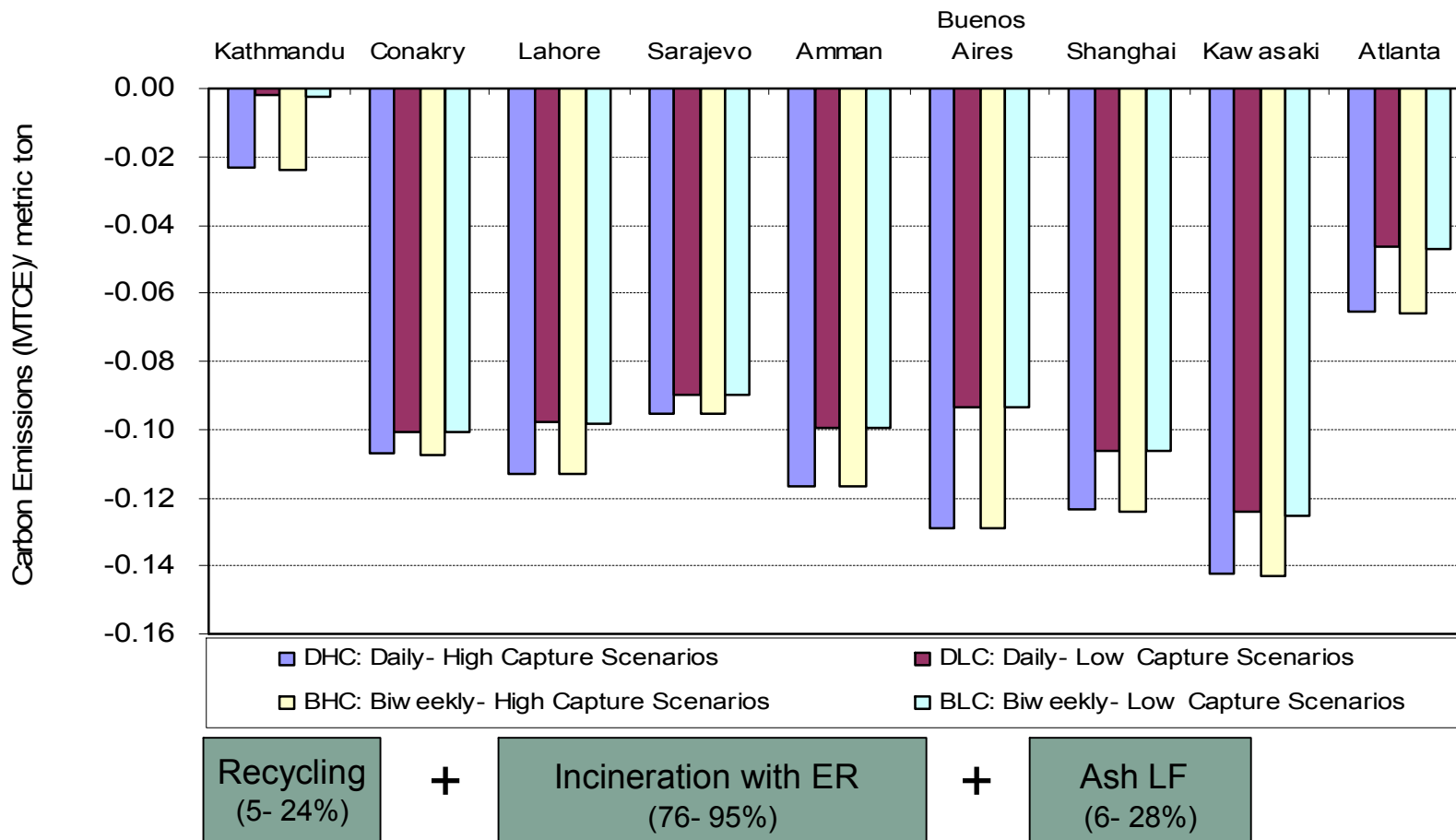
- The most effective strategies for minimizing emissions included materials recycling and energy recovery.
- The electricity grid mix is a key indicator for carbon and criteria type air emissions and savings
  - Some cities (e.g., Katmandu) have high percentages of hydroelectricity and thus in these cities, electricity-related emissions are close to zero.
  - Some cities (e.g., Amman) have high percentages of natural gas in their grid mix and thus in these cities, electricity-related PM emissions are close to zero.
- Recyclables composition and quantity are key in determining emission savings.
  - Again, metals recycling creates significant benefits.
  - Some materials have emission burdens associated with remanufacturing (e.g., corrugated cardboard and office paper)

# Emissions Findings (cont.)

- Landfill gas management can greatly reduce landfill-related GHG emissions.
  - Largest reductions were observed when moving from uncontrolled to controlled and managed (via flare or gas-to-energy)
  - Organics diversion (via recycling, composting, incineration) can greatly reduce net GHG emissions.



# Emissions Findings Example: Optimization of Carbon Emission Reductions

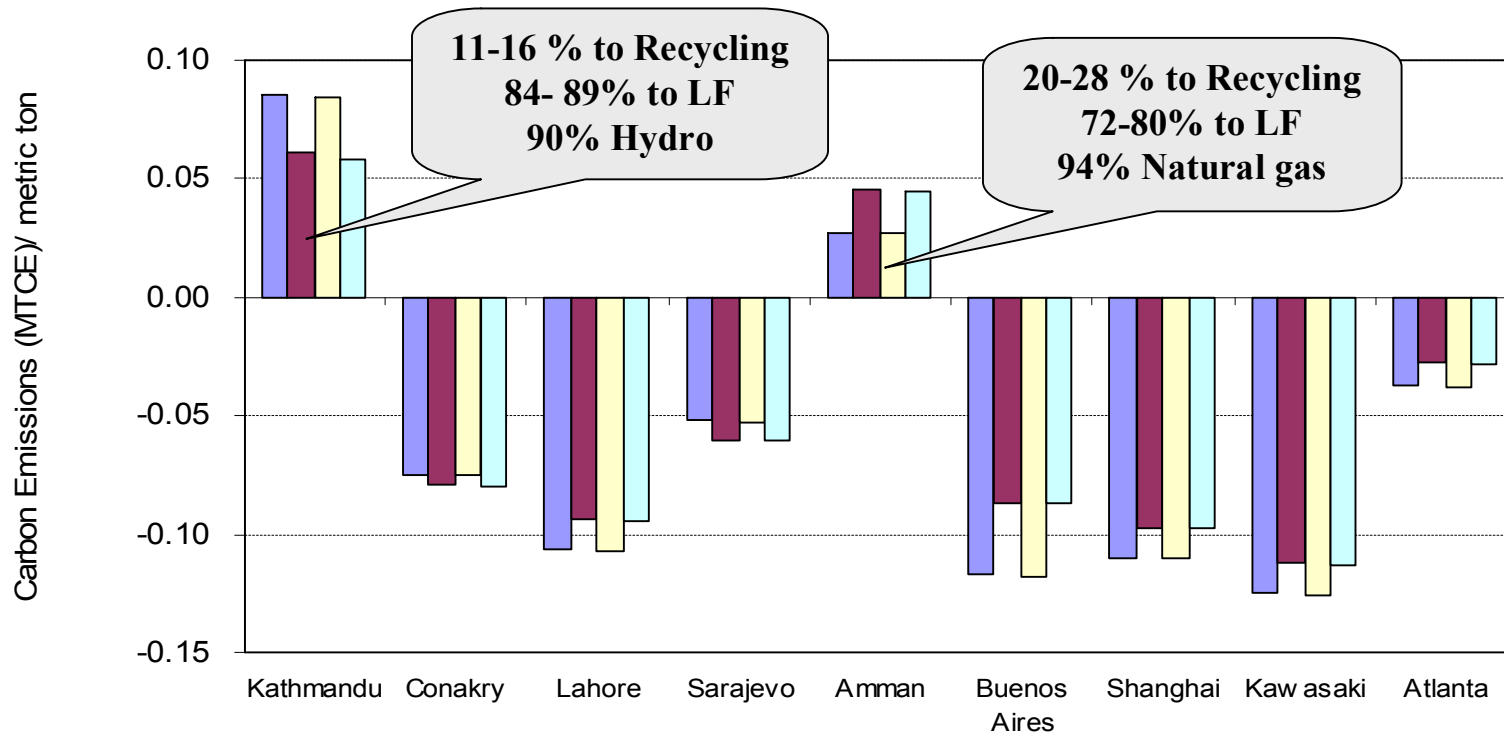


# Impact of Key Parameters on Net Carbon Emissions

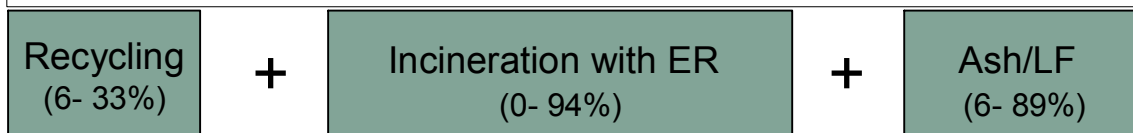
- ↓ Waste heating content
- ↓ Percent coal in electricity grid
- ↓ Percent recyclables (esp. metals)
- ↑ Percent hydro in electricity grid mix
- ↑ Energy (electricity and fuels) consumed



# Emissions Finding Example: Carbon Results When Goal Was Minimizing PM



■ DHC: Daily- High Capture Scenarios      ■ DLC: Daily- Low Capture Scenarios  
■ BHC: Biweekly- High Capture Scenarios      ■ BLC: Biweekly- Low Capture Scenarios



# Overall Findings

- The results obtained for cities in similar income categories did not show common trends as initially thought.
- Results are very sensitive to input parameters which did not exhibit similarities by income category, such as:
  - Recyclables composition
  - Electricity grid mix



# Uncertainties and Limitations

- The model builds used a combination of city-specific and North American default data and thus not always a complete reflection of regional conditions.
  - Results only as good as the input data collected and used.
  - Cost data, in particular capital and O&M costs, were very difficult to obtain.
  - Energy and materials production data based on North American processes.
- Did not model current waste management practices.
- Results are a snap-shot and best considered in the context of providing relative tradeoffs rather than absolutes.
  - No distinction between local, national, and global emissions.
  - Current technology, limited consideration of future improvements.
- Results sensitivity to some key parameters was evaluated. Further investigation could be useful:
  - Defining breakpoints for key parameters.

# Acknowledgements

- Sandra Cointreau (World Bank)
- Nancy Cunningham-Wilson (consultant)
- Shungo Soeda, Satoshi Higashinakagawa, Pirran Driver, Mitsuhiro Doya, Takahiro Kamishita, and Juan Martin Coutoudjian (Nippon Koei)
- Susan Thorneloe and Ozge Kaplan (US EPA, Office of Research and Development)