

# Environmental Footprinting Brownfields vs. Greenfields

Western Pennsylvania Brownfields Center

Carnegie Mellon

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# EPA Training, Research and Technical Assistance Project

- Training - working with network of Main Street and Elm Street Managers across PA
- Technical Assistance - developing a multi-attribute decision-making tool to assist in prioritizing sites
- Research

What is the environmental footprint of a Brownfield development as compared to a Greenfield development?



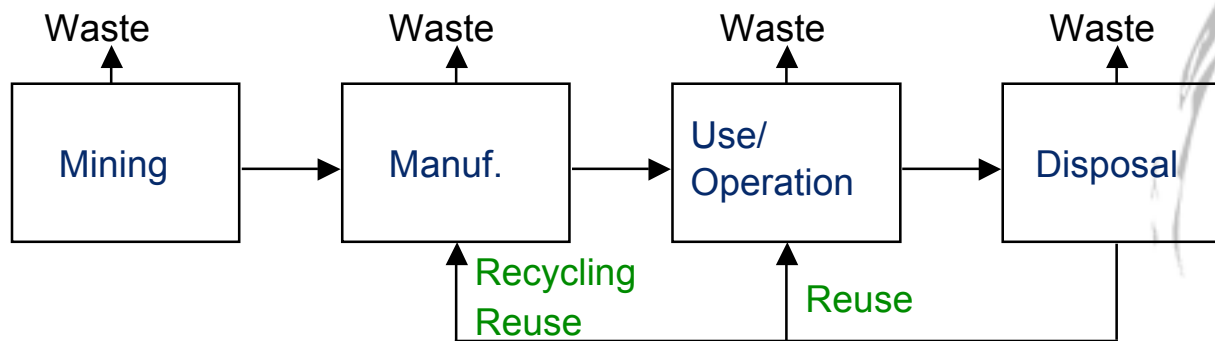
# Quantifying a Sustainable Brownfield

- Goal to evaluate life cycle implications of brownfield development vs greenfield development
- Impact on climate change - until now, there has been no mechanism to quantify
- Carbon footprint as well as environmental contaminants
  - $\text{NO}_2$ ,  $\text{SO}_2$ , CO, VOC's
- Base tool: EIO-LCA Model developed at Carnegie Mellon (plus other process models)



# EIO-LCA

- Economic Input-Output -- “General interdependency” model: quantifies the interrelationships among sectors of an economic system
- Life Cycle Assessment -- studies analyze the environmental aspects and potential impacts throughout a product's life cycle (e.g., cradle-to-grave) from raw material acquisition through production, use and disposal



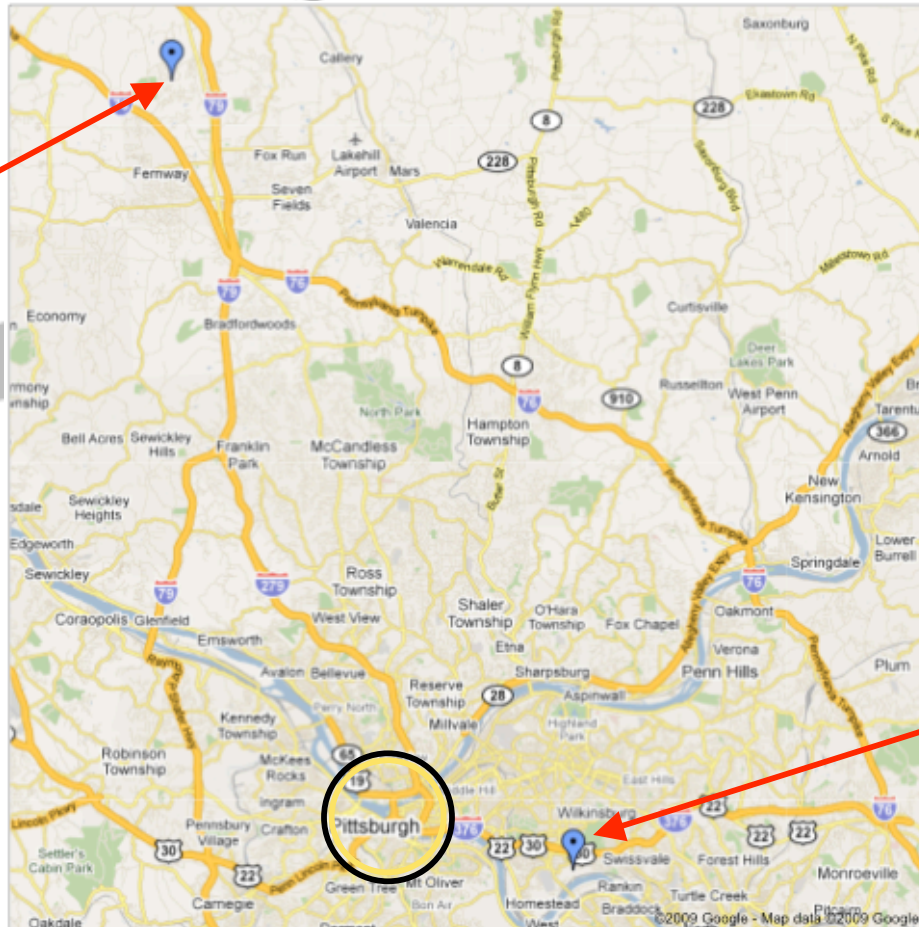
# Caveat Emptor

- Data reliability and quality is often questionable.
- Models based on assumptions - and national level data
- Problem boundaries are often arbitrary.
- Scale issues - global -> local, etc.
- **Uncertainty** is everywhere
- Spatial and temporal issues increase uncertainty
- Comparisons between studies difficult without pushing into study details
- Cost and time of conducting life cycle assessment study is considerable.



# Comparing a Brownfield and a Greenfield in Pittsburgh

Cranberry Heights



Summerset at Frick Park



# Our Two Residential Sites

## BF: Summerset

## GF: Cranberry Heights

• Area	32 acres	269 acres
• Number of Units	159	244
• Persons per Unit	2.1	3.7
• Living Space / Unit (average)	2,700sf	2,700sf
• Distance to Work	5.4 miles	21 miles
• Distance to School	2.9 miles	6 miles
• Annual Private Vehicle Usage	14,700 miles	30,450 miles
• Surveys Returned	40	75



# What to compare?

- Construction Phase
  - Remediation
  - Site development
    - Grading
    - Infrastructure improvements
  - Structures
- Use Phase
  - Private residents
    - Utilities
    - Travel
    - Maintenance
  - Common space
    - Utilities
    - Maintenance
  - CO<sub>2</sub> Terrestrial sequestration



Note that we are not addressing the 'disposal' phase



# How to Compare: Construction Phase

- Economic Input Output - Life Cycle Assessment
- Based on dollars spent in certain economic sector - data assembled by Dept of Commerce, Bureau of Economic Analysis
- 'Breakdown' construction costs into sectors that match BEA sectors
- Environmental data also maps onto sectors
  - Source: Environmental Protection Agency, Energy Information Administration



# Specifically, the EIO-LCA model:

- Can

- Use publicly available data
- Consider many sectors in the supply chain
- Estimate emissions on the basis of the magnitude of the effort (\$\$)

- Cannot

- Differentiate between remediation and other similar construction
- Account for site specific 'greening' improvements

But, process methods might be used to supplement



# Sectors that Might be Applied to BF/GF Development

- Broad Sector: Construction
  - Manufacturing and Industrial Buildings
  - Highway, Street, Bridge and Tunnel Construction
  - Water, Sewer and Pipeline Construction
- Broad Sector: Professional and Technical Services
  - Architectural and Engineering Services
  - Environmental and Other Technical Consulting Services



# EIOLCA.NET

Carnegie Mellon

Green Design  
INSTITUTE

Use Standard Models

Create Custom Model

Documentation

## 1 Choose a model:

Your current model is the **Industry Benchmark US Dept of Commerce EIO model from 1997**, which is a **Producer Price Model**. ([Show more details](#))

US 1997 (491)

## 2 Select industry and sector:

Search for a sector by keyword:

Or browse for a sector below:

Select a Broad Sector Group  Select a Detailed Sector

Commercial and  
Industrial Buildings

## 3 Select the amount of economic activity for this sector:

1 Million Dollars ([Show more details](#))

## 4 Select the category of results to display:

Economic Activity ([Show more details](#))

Construction

## 5 Run the model:

You must select a sector in order to run the model.



# Economic Activity

	<u>Sector</u>	<u>Total Economic Value Added</u> <u>\$mill</u>	<u>Direct Economic</u> <u>\$mill</u>	<u>Direct Economic</u> <u>%</u>	
	<i>Total for all sectors</i>	2.00	0.992	1.52	76.0
230220	Commercial and institutional buildings	1.00	0.479	1.00	100.0
541300	Architectural and engineering services	0.091	0.065	0.084	91.8
420000	Wholesale trade	0.057	0.038	0.027	46.8
4A0000	Retail trade	0.050	0.030	0.046	93.9
550000	Management of companies and enterprises	0.027	0.019	0.003	9.73
531000	Real estate	0.026	0.018	0.008	30.7
484000	Truck transportation	0.022	0.011	0.009	41.7
513300	Telecommunications	0.018	0.010	0.009	46.6
332312	Fabricated structural metal manufacturing	0.018	0.008	0.015	83.2
324110	Petroleum refineries	0.017	0.002	0.009	50.9

- Given \$1,000,000 in the Construction Sector, Commercial and Industrial Buildings
- Top 10 sectors
- Data source: Bureau of Economic Analysis (BEA), US Department of Commerce



# Conventional Air Pollutants

	<u>Sector</u>	<u>SO2</u> <u>mt</u>	<u>CO</u> <u>mt</u>	<u>NOx</u> <u>mt</u>	<u>VOC</u> <u>mt</u>	<u>Lead</u> <u>mt</u>	<u>PM10</u> <u>mt</u>
	<i>Total for all sectors</i>	1.05	5.48	2.01	1.01	0.000	0.413
221100	Power generation and supply	0.652	0.032	0.295	0.003	0.000	0.014
327310	Cement manufacturing	0.096	0.062	0.122	0.096	0.000	0.015
541300	Architectural and engineering services	0.048	0.070	0.037	0.019	0	0.011
331411	Primary smelting and refining of copper	0.025	0.000	0	0.001	0.000	0.003
212310	Stone mining and quarrying	0.025	0.046	0.018	0.009	0	0.005
331111	Iron and steel mills	0.022	0.191	0.018	0.011	0.000	0.016
324110	Petroleum refineries	0.019	0.011	0.004	0.015	0	0.002
331312	Primary aluminum production	0.017	0.094	0	0.001	0	0.004
331311	Alumina refining	0.015	0	0.004	0.003	0	0.001
211000	Oil and gas extraction	0.015	0.025	0.011	0.017	0	0.000

- Given \$1,000,000 in the Construction Sector, Commercial and Industrial Buildings
- Top 10 sectors
- Data source: US Environmental Protection Agency - point source data with industry markers that are mapped onto the I-O sectors



# Energy

	<u>Sector</u>	<u>Total</u> <u>TJ</u>	<u>Elec</u> <u>MkWh</u>	<u>Coal</u> <u>TJ</u>	<u>NatGas</u> <u>TJ</u>	<u>LPG</u> <u>TJ</u>	<u>MotGas</u> <u>TJ</u>	<u>Distillate</u> <u>TJ</u>	<u>Kero</u> <u>TJ</u>	<u>JetFuel</u> <u>TJ</u>	<u>Residual</u> <u>TJ</u>
	<i>Total for all sectors</i>	7.72	0.251	1.38	1.92	0.498	0.241	3.05	0.000	0.231	0.124
230220	Commercial and institutional buildings	3.25	0.058	0	0.226	0.315	0.020	2.54	0	0.082	0
221100	Power generation and supply	1.43	0.000	1.13	0.253	0.000	0.000	0.000	0	0	0.043
484000	Truck transportation	0.250	0.000	0	0.005	0.000	0.036	0.207	0	0	0
331111	Iron and steel mills	0.248	0.012	0.012	0.211	0.000	0.002	0.001	0	0.000	0.008
327310	Cement manufacturing	0.235	0.008	0.152	0.068	0.000	0.004	0.002	0	0	0.000
324110	Petroleum refineries	0.218	0.004	0	0.106	0.099	0.000	0.000	0	0.000	0.008
481000	Air transportation	0.116	0.000	0	0.000	0	0.002	0	0	0.113	0
420000	Wholesale trade	0.075	0.005	0.000	0.033	0.002	0.009	0.024	0	0.000	0.001
3221A0	Paper and paperboard mills	0.074	0.004	0.019	0.038	0.000	0.000	0.000	0	0	0.011
4A0000	Retail trade	0.066	0.011	0.000	0.031	0.000	0.003	0.020	0	0	0

- Given \$1,000,000 in the Construction Sector, Commercial and Industrial Buildings
- Top 10 sectors
- Data source: based on fossil fuel and 31% electricity use per sector (31% of electricity from non-fossil fuels)





# Greenhouse Gases

	<u>Sector</u>	<u>GWP</u> <u>MTCO2E</u>	<u>CO2</u> <u>MTCO2E</u>	<u>CH4</u> <u>MTCO2E</u>	<u>N2O</u> <u>MTCO2E</u>	<u>CFCs</u> <u>MTCO2E</u>
	<i>Total for all sectors</i>	599.	538.	41.3	9.49	9.55
230220	Commercial and institutional buildings	212.0	212.0	0	0	0
221100	Power generation and supply	120	119.0	0	0	1.44
484000	Truck transportation	34.8	34.3	0.053	0.479	0
327310	Cement manufacturing	27.2	27.2	0	0	0
562000	Waste management and remediation services	20.2	3.19	17.0	0.025	0
331111	Iron and steel mills	19.6	19.6	0	0	0
211000	Oil and gas extraction	14.3	2.40	11.9	0	0
324110	Petroleum refineries	11.7	11.7	0.065	0	0
481000	Air transportation	7.49	7.40	0.009	0.080	0
486000	Pipeline transportation	6.56	3.16	3.41	0	0

- Given \$1,000,000 in the Construction Sector, Commercial and Industrial Buildings
- Top 10 sectors
- Data source: Based on fuel use, fossil fuel use from I-O model, 1997 prices, conversion factors (physical constants, EPA, EIA)





# Toxic Releases

	<u>Sector</u>	<u>Non-Point Air kg</u>	<u>Point Air kg</u>	<u>Tot Air Releases kg</u>	<u>Water Releases kg</u>	<u>Land Releases kg</u>	<u>U'ground Releases kg</u>	<u>Total Releases kg</u>	<u>POTW Transfers kg</u>	<u>Offsite Transfers kg</u>	<u>Total Ral/Trans kg</u>
	Total for all sectors	16.0	72.0	88.0	15.1	301.	16.0	420	17.8	51.9	489.
324110	Petroleum refineries	0.995	1.49	2.49	0.942	0.051	0.118	3.60	0.187	0.190	3.97
332312	Fabricated structural metal manufacturing	0.854	0.359	1.21	0.000	0.103	0	1.32	0.042	0.473	1.83
32619A	Plastics plumbing fixtures and all other plastics products	0.817	3.69	4.50	0.011	0.005	0	4.52	0.186	0.391	5.10
325211	Plastics material and resin manufacturing	0.815	1.77	2.58	0.192	0.010	0.941	3.72	1.53	0.226	5.48
325190	Other basic organic chemical manufacturing	0.733	1.25	1.98	0.742	0.043	2.11	4.88	1.69	0.626	7.19
3261A0	Foam product manufacturing	0.593	1.07	1.66	0	0.007	0	1.67	0.000	0.007	1.68
331111	Iron and steel mills	0.544	0.507	1.05	6.85	4.56	0.074	12.5	0.180	23.1	35.8
325510	Paint and coating manufacturing	0.525	0.750	1.27	0.020	0.012	0.000	1.31	0.254	0.353	1.91
331312	Primary aluminum production	0.516	1.61	2.13	0.009	0.186	0	2.32	0.000	0.468	2.79
325110	Petrochemical manufacturing	0.452	0.631	1.08	0.448	0.025	1.53	3.09	1.25	0.474	4.82

- Given \$1,000,000 in the Construction Sector, Commercial and Industrial Buildings
- Top 10 sectors
- Data source: EPA's Toxic Release Inventory



# Employment

	<u>Sector</u>	<u>Total Employees</u>
	<i>Total for all sectors</i>	10.4
230220	Commercial and institutional buildings	2.03
420000	Wholesale trade	1.32
4A0000	Retail trade	0.949
541300	Architectural and engineering services	0.724
561300	Employment services	0.489
115000	Agriculture and forestry support activities	0.212
484000	Truck transportation	0.176
550000	Management of companies and enterprises	0.142
32619A	Plastics plumbing fixtures and all other plastics products	0.132
332312	Fabricated structural metal manufacturing	0.110

- Given \$1,000,000 in the Construction Sector, Commercial and Industrial Buildings
- Top 10 sectors
- Data source: Census, Bureau of Labor Statistics and others



# How to Compare: Use Phase

- Utility bills
  - Cost => units => emissions per unit
    - Source: EIA and utility conversion factors
- Transportation
  - Private
    - Annual miles => fuel efficiency => emissions per unit
      - Source: EIA conversion factors
  - Public
    - Annual miles => fuel efficiency => emissions per trip
      - Source: National Transit Database
        - Fuel by mode and usage data
- Other 'greening' aspects
  - ie, CO2 Terrestrial Sequestration
    - process models and conversion factors



# Example - Gas

- Pipeline conveyance - 5 lb eCO<sub>2</sub> per \$ (EIO-LCA)
- Emissions from burning - 10 lb eCO<sub>2</sub> per \$ (process)
- Total: 15 lb eCO<sub>2</sub> per \$ of household gas bill
- ✓ \$100 per month gas bill = 1500 lb eCO<sub>2</sub> per month
- ✓ Times months per year = annual household emissions = 18,000 lb eCO<sub>2</sub>



# Example - Electricity

- Supply chain - 20 lb eCO<sub>2</sub> per \$ (EIO-LCA)
  - ✓ \$100 per month electric bill = 2000 lb eCO<sub>2</sub> per month
  - ✓ Times months per year = annual household emissions = 24,000 lb eCO<sub>2</sub>



# Example - Personal Vehicle

- Process conversion - 1 lb eCO<sub>2</sub> per Vehicle Mile Traveled (EIA - based on emissions per gallon and average miles per gallon)
- ✓ Average VMT (per household) of 24,000 miles = 24,000 lb eCO<sub>2</sub>



# Total per Household

- Gas = 18,000 lb eCO<sub>2</sub>
- Electric = 24,000 lb eCO<sub>2</sub>
- VMT = 24,000 lb eCO<sub>2</sub>
- **TOTAL (annual) = 66,000 lb eCO<sub>2</sub>**



# Brownfield vs. Greenfield: Use Phase

	<b>Brownfield 1</b>	<b>Greenfield 1</b>
	<b>(lb eCO<sub>2</sub>)</b>	<b>(lb eCO<sub>2</sub>)</b>
Utilities		
Gas	20400	35000
Electric	30000	38300
Water	2300	4100
VMT		
Private	15300	31700
Public	1250	7850
<b>TOTAL PER HOUSEHOLD</b>	<b>69250</b>	<b>116950</b>

LOOKING FOR OTHER BF::GF PAIRS





# Preliminary Findings

- Construction phase: Emissions from brownfield site preparation efforts are greater than greenfield
  - Excess earthwork
- Use phase: Utility and travel related emissions seem to be less for brownfield residents than for greenfield residents
  - Shorter commutes
  - Smaller houses



# Challenges (for instance)

- Construction Phase
  - Defining limit of remediation
  - Accounting for offsite infrastructure
  - Mapping costs to EIO-LCA sectors
- Use Phase
  - Response rate of residents
  - Accounting for common space
  - Accounting for 'school buses'

## Reporting units:

- ✓ ...per household
- ✓ ...per capita
- ✓ ...per acre
- ✓ ...per square foot of living space

???



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