Lecture #42

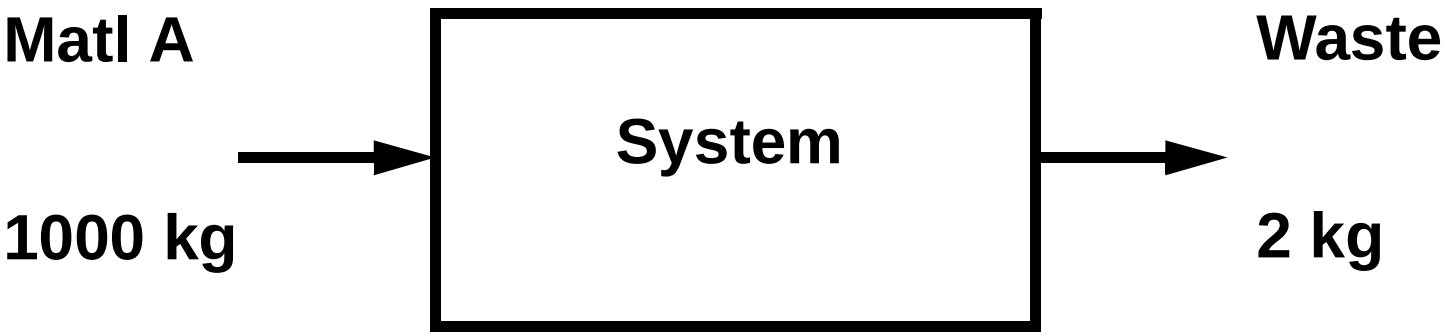
ERDM

Prof. John W. Sutherland

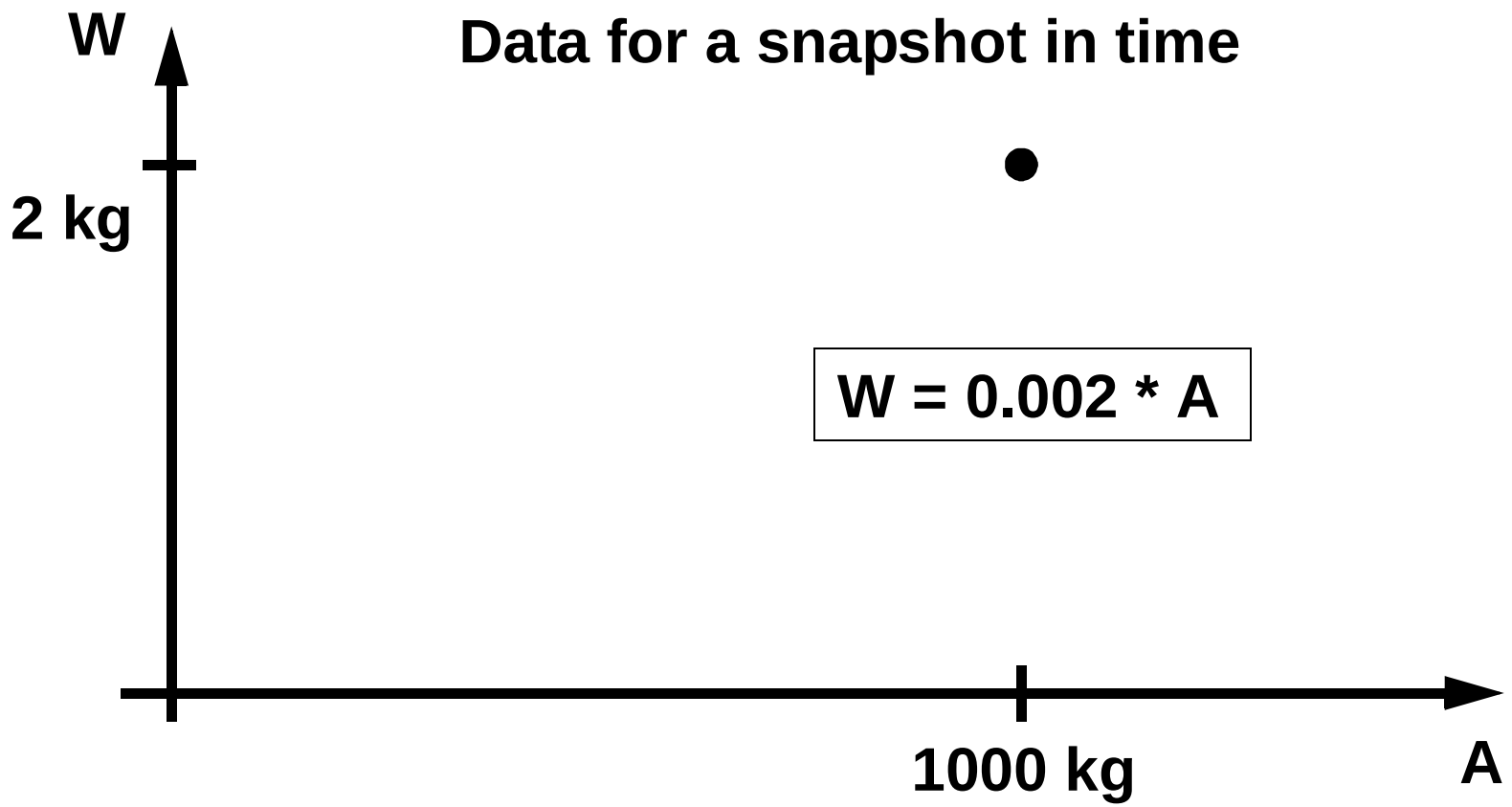
April 23, 2004

EIO-LCA

- **EIO-LCA (Economic Input/Output - Life Cycle Assessment)**
- **Input / Output Analysis??**



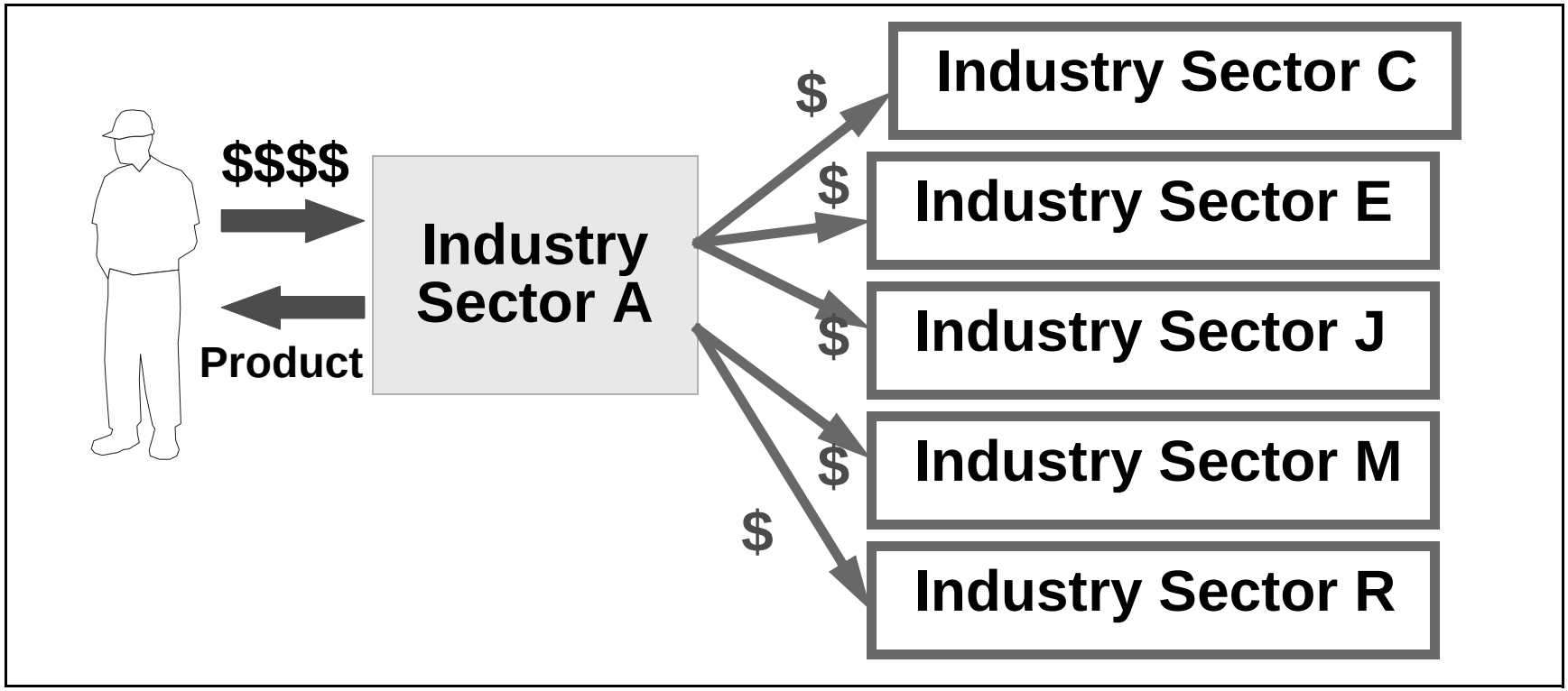
Simple Input - Output Analysis



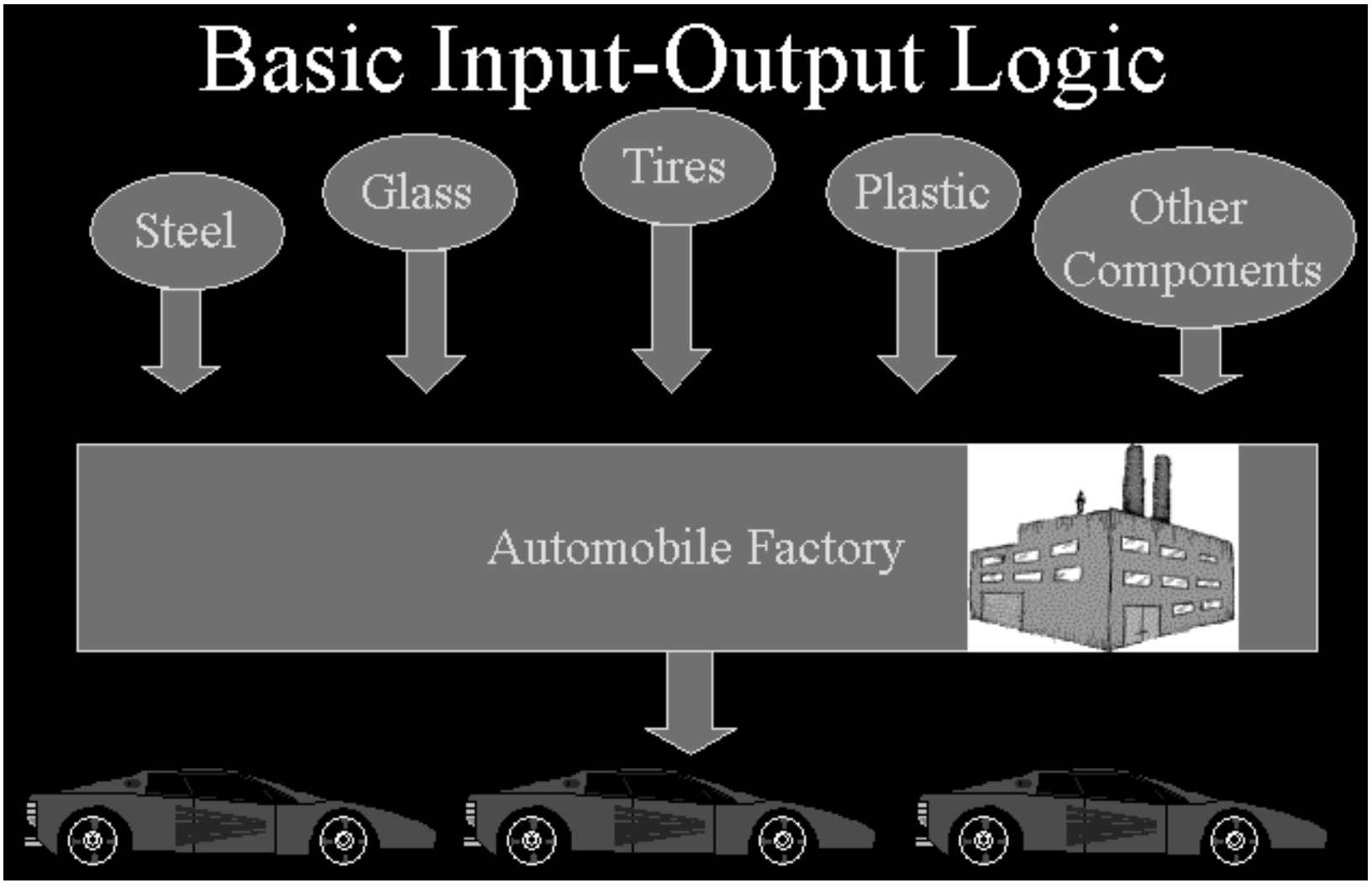
What are I-O models?

- **Used to capture inter-industry/system transactions.**
- **Industries use the products of other industries to produce their own products**
  e.g. - Automobile manufacturers rely on products from chemical, metal, electronics, tire, etc. industries
- **Outputs from one industry become inputs to another industry**
- **When you buy a car, the demand for steel, glass, plastic, etc. is affected.**

More on EIO Basic Idea



A $1000 purchase results in way more than $1000 in total activity. Where to invest to get best total impact?



Assumptions

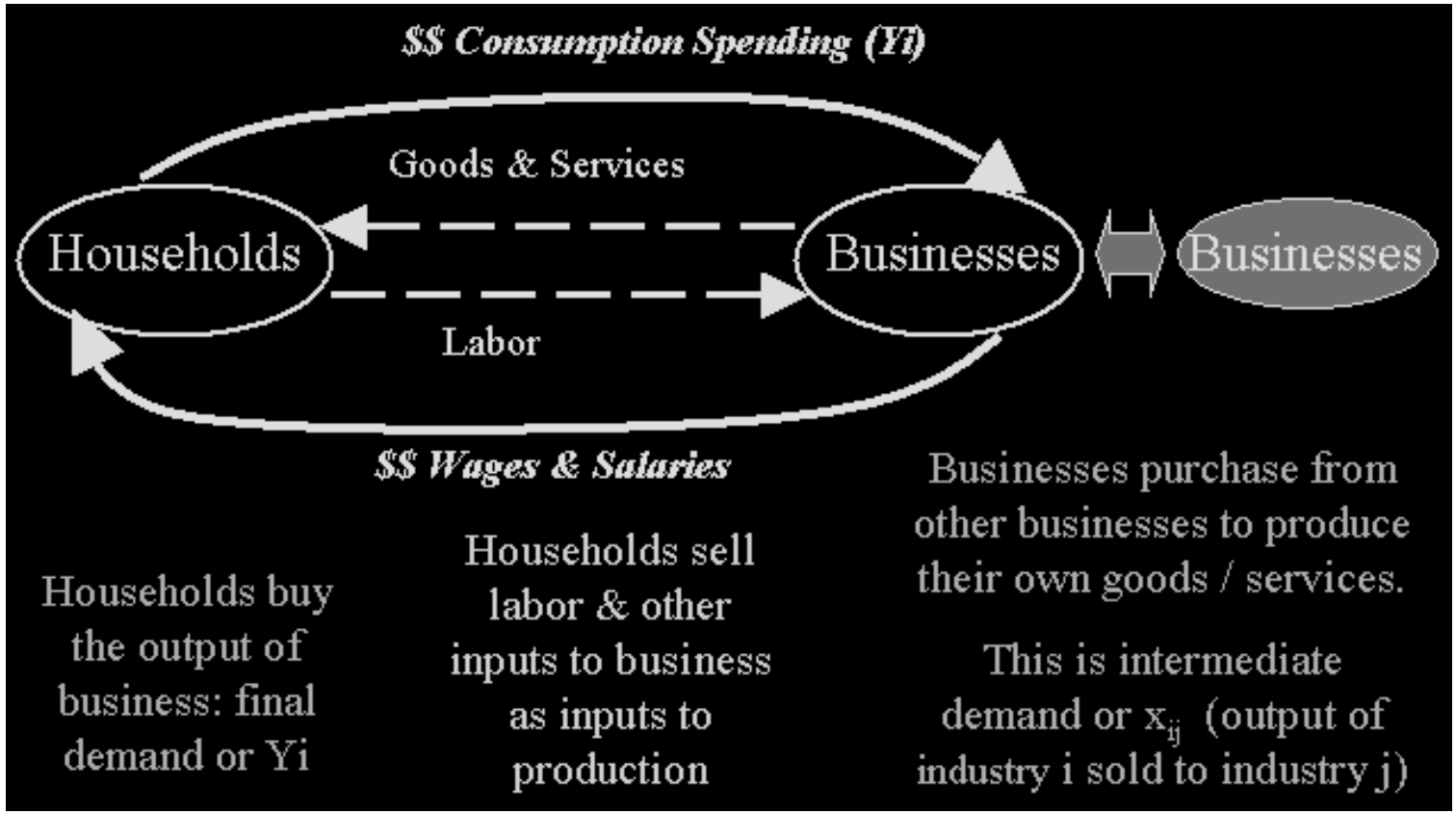
- **The economy/system is divided into *n* sectors [sectors - individuals, companies, nations,etc.]**
- **Each sector produces exactly one output**
- **One non-product - Labor**
- **Constant returns to scale [To increase output by ‘A’, scale input by ‘A’]**
- **No choice of production techniques [No substitution possible between inputs]**

Temporal Distinctions of I-O models

- **Static - Snap-shot of a system in motion. Represents phenomena at a single interval of time**
- **Comparative Static - Succession of snap-shots. Compares phenomena at several instances of time**
- **Dynamic - relation of a frame to the succeeding frame. Shows how phenomena within an interval are related to activities outside the interval**
- **Comparative Dynamic - comparison of two segments of motion picture**

Economic I-O Analysis

Method to systematically quantify the interrelationships among various sectors of an economic system.



Model Formulation

X_i : Entire output of industry sector i -- in $$$$

$$X_i = Z_{i1} + Z_{i2} + Z_{i3} + \ldots + Y_i$$

$$X_i = \Sigma Z_{ij} + Y_i$$

Z_{ij} : Output of industry sector i sold to industry sector j

Y_i : Final demand for sector i's products (other than inter-industry exchanges) -- Govt., export, etc.

Inter-industry Demand

$$Z_{ij} = a_{ij} \cdot X_j$$

Z_{ij} : Output of sector i sold to sector j

X_j : Output of sector j

a_{ij} : Input-output coefficient ($0 < a_{ij} < 1$)

$$X_i = a_{i1} \cdot X_1 + a_{i2} \cdot X_2 + a_{i3} \cdot X_3 + \ldots + Y_i$$

$$X_i = \Sigma a_{ij} \cdot X_j + Y_i \quad \textbf{or} \quad X_i - \Sigma a_{ij} \cdot X_j = Y_i$$

Matrix Form

In matrix form the complete n x n system is:

$(I - A)X = Y$, where, A - matrix of input output coefficients

If $| I - A |$ is not equal to zero, $(I - A)^{-1}$ can be determined.

Therefore, $X = (I - A)^{-1} Y$

Here $(I - A)^{-1}$ is known as the LEONTIEF INVERSE.

Example

Consider two hypothetical sectors

		To Processing Sectors		Final Demand	Total Output
		1	2	(Y_i)	(X_i)
From Processing Sectors	1	150	500	350	1000
	2	200	100	1700	2000
Payments (value added)		650	1400		
Total Outlays	(X_i)	1000	2000		

Since $X = (I-A)^{-1}Y$, we can describe how sector outputs, X's, will change when Y changes.

Example (cont.)

Input output coefficients:

a_{11} = 150/1000 = 0.15

a_{12} = 500/2000 = 0.25

Therefore, $\mathbf{A} = \begin{bmatrix} 0.15 & 0.25 \\ 0.20 & 0.05 \end{bmatrix}$ **&** $\mathbf{Y} = \begin{bmatrix} 350 \\ 1700 \end{bmatrix}$ **,** $\mathbf{X} = \begin{bmatrix} 1000 \\ 2000 \end{bmatrix}$

Analyze how sector 1 & 2 outputs are affected if final demand for sector 1 is increased from $350 to $400 and that of sector 2 is reduced from $1700 to $1600.

Example (cont.)

From problem statement, $\mathbf{Y} = \begin{bmatrix} 400 \\ 1600 \end{bmatrix} \sim \mathbf{Y} = \begin{bmatrix} 50 \\ -100 \end{bmatrix}$

Also, $(\mathbf{I} - \mathbf{A}) = \begin{bmatrix} 0.85 & -0.25 \\ -0.20 & 0.95 \end{bmatrix}$ **and** $(\mathbf{I} - \mathbf{A})^{-1} = \begin{bmatrix} 1.254 & 0.33 \\ 0.264 & 1.122 \end{bmatrix}$

$$\mathbf{dX} = (\mathbf{I} - \mathbf{A})^{-1} \cdot \mathbf{dY} = \begin{bmatrix} 1.254 & 0.33 \\ 0.264 & 1.122 \end{bmatrix} \cdot \begin{bmatrix} 50 \\ -100 \end{bmatrix} = \begin{bmatrix} 29.7 \\ -99 \end{bmatrix}$$

The change in demand produces an increase in sector 1 output of $29.7 and a decrease in sector 2 output of $99.0.

EIO-LCA

(http://www.eiolca.net/)

- **The model divides the U.S. economy into roughly 500 sectors.**
- **The model can be visualized as a large table (or matrix) with 500 rows and 500 columns, with one row and one column for each sector**
- **Economic matrix is augmented with environmental impact indices, used to analyze economy-wide environmental impacts of changes in the output of selected industrial sectors.**

EIO-LCA

- **The environmental effects estimated include:**
  - **Electricity consumption,**
  - **Fuel use, Ore consumption,**
  - **Fertilizer use, Water consumption**

- **Environmental outputs:**
  - **Toxic emissions from the Toxics Release Inventory (TRI),**
  - **Toxicity-weighted chemical emissions (CMU-ET),**
  - **RCRA hazardous waste generation/management,**
  - **Ozone depletion & Global warming potentials,**
  - **Conventional pollutant emissions**

Example of an eiolca.net Application

- **$1,000,000 spent to purchase vehicles.**

Effects	Total all sectors
Economic Purchases [$ million]	2.805601
Electricity Used [MkW-hr]	0.619805
Energy Used [TJ]	14.247421
Conventional Pollutants Released [metric tons]	12.123697
OSHA Safety [fatalities]	0.000611
Greenhouse Gases Released [metric tons CO2 equiv.]	1015.733333
Fertilizers Used [$ million]	0.000313
Fuels Used [metric tons]	387.640473
Ores Used - at least [metric tons]	326.117099
Hazardous Waste Generated [RCRA, metric tons]	47.438562
External Costs Incurred [median, $ million]	0.027846
Toxic Releases and Transfers [metric tons]	2.023702
Weighted Toxic Releases and Transfers [metric tons]	11.583339
Water Used [billion gallons]	0.006308

- **$1,000,000 to a University**

Effects	Total all sectors
Economic Purchases [$ million]	1.765978
Electricity Used [MkW-hr]	0.182479
Energy Used [TJ]	4.376041
Conventional Pollutants Released [metric tons]	5.138401
OSHA Safety [fatalities]	0.000634
Greenhouse Gases Released [metric tons CO2 equiv.]	298.175632
Fertilizers Used [$ million]	0.000184
Fuels Used [metric tons]	110.132634
Ores Used - at least [metric tons]	34.658559
Hazardous Waste Generated [RCRA, metric tons]	13.064121
External Costs Incurred [median, $ million]	0.011248
Toxic Releases and Transfers [metric tons]	0.193479
Weighted Toxic Releases and Transfers [metric tons]	1.017710
Water Used [billion gallons]	0.001088