Economic Input-Output Life Cycle Analysis

Lester Lave, Chris Hendrickson, & Scott Matthews

Green Design Institute

Carnegie Mellon University

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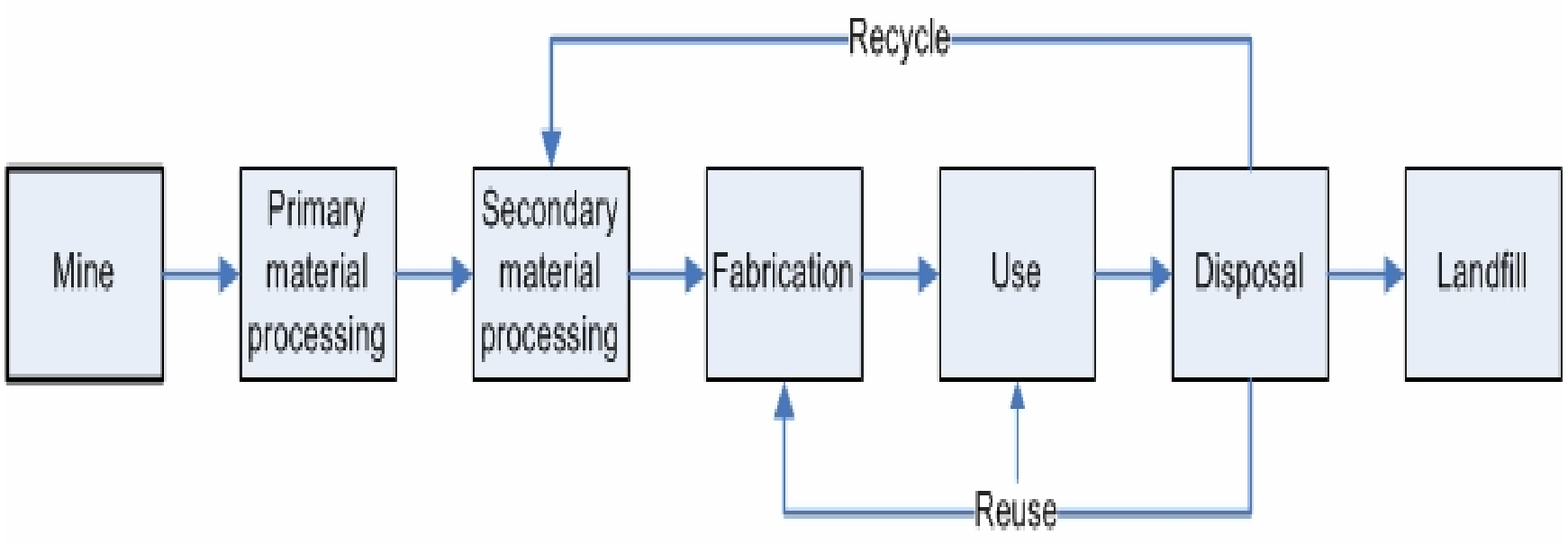
Why Life Cycle Analysis?

- Social Goal: Better environmental quality & a more sustainable economy
- Focusing on one phase is misleading: Battery powered cars, hydrogen cars
- Need to examine all materials & energy going in & all discharges coming out from “cradle to grave” – extraction to disposal
- ISO 14000 has defined a protocol for LCA

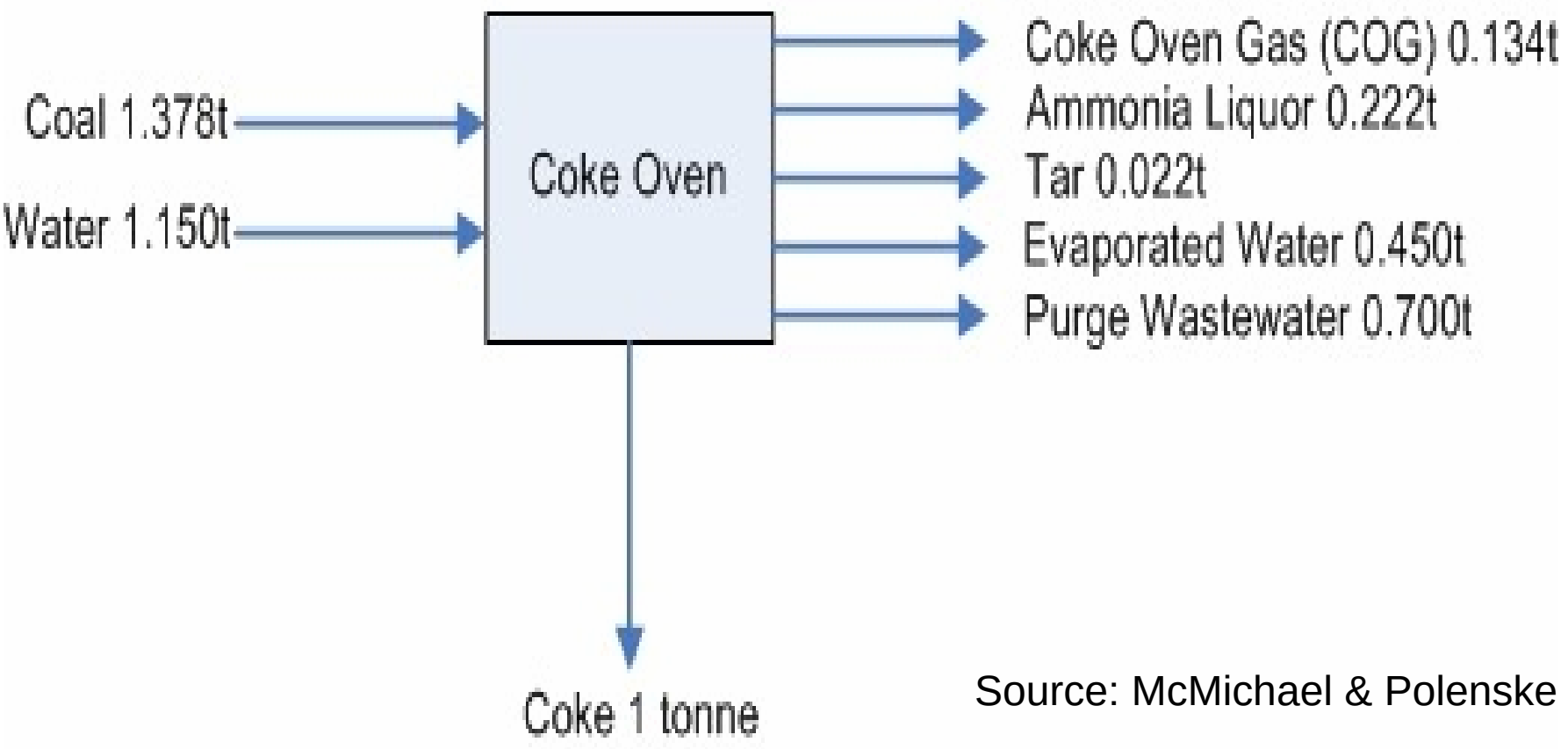
Life Cycle Analysis: Extraction to End of Disposal Need to Account for Indirect Inputs



Process Analysis: SETAC

- Until recently, LCA was done only by doing detailed materials & energy balances of each relevant process
- This is time consuming & expensive, e.g., multi-million dollar US automobile study
- Cannot examine all contributing processes & so need to draw, arbitrarily, a boundary as to what is considered – most is left out

Simplified Process Analysis: Materials Balance for Coke Oven

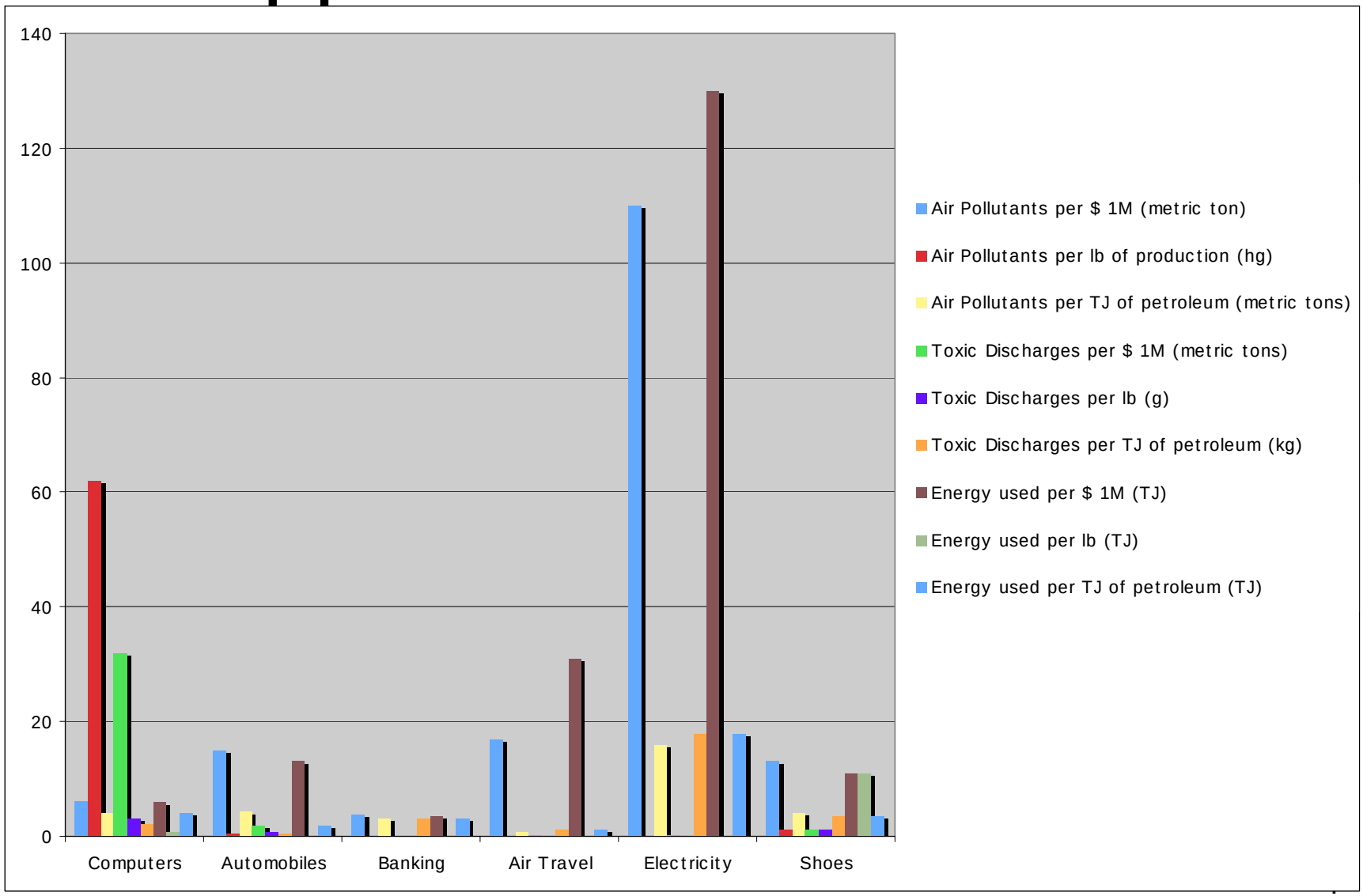


Source: McMichael & Polenske

LCA Too Complicated!

- Materials & energy balances for thousands (millions?) of processes?
- Can’t we just approximate an LCA?
- LCA proportional to cost, weight, or petroleum use of a good or service
- Is each dollar of economic activity equally consumptive of resources
- Is each pound of a product?
- Is each liter of petroleum used?

Approximations to LCA



From I-O to EIO-LCA

- To US Input-Output table we append government data bases available by I-O sector: Inputs of energy, fuels, emissions of air pollutants & greenhouse gases, water use, occupational injury & death, waste discharged, etc.
- To do an LCA, we approximate each input by an I-O sector
- We observe direct, & compute indirect, inputs with implied outputs & discharges

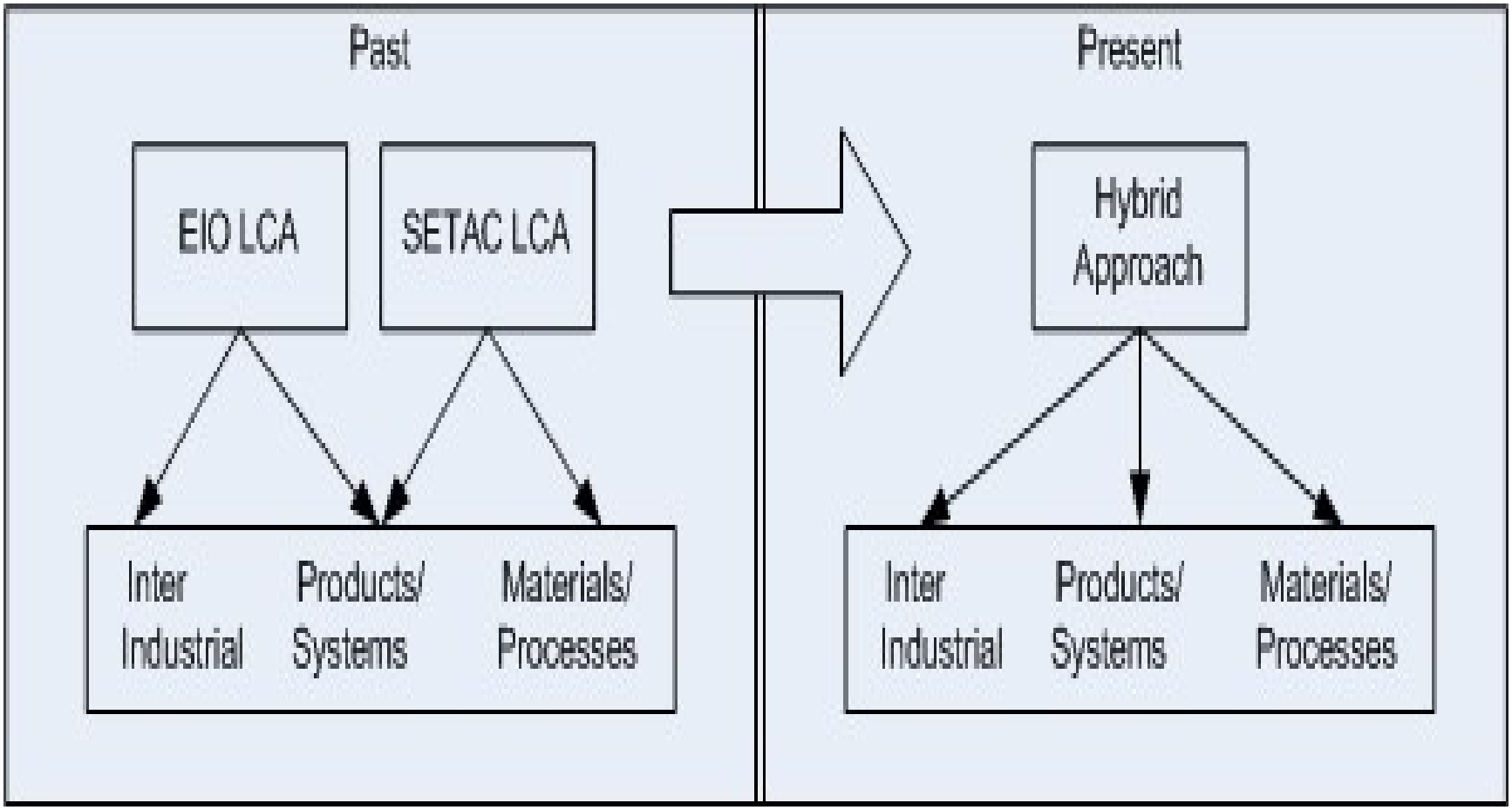
Supply Chain: Making $1 million of Computer Peripherals Equipt. in 1997 ($)

Total for all supply sectors	2,985,000
Computer peripheral equipment	1,083,000
Semiconductors & related devices	347,000
Wholesale trade	241,000
Other electronic components	211,000
Noncomparable imports	73,000
Motors & generators	60,000
Miscellaneous plastics products	48,000
Real estate	45,000
Advertising	43,000

$1 million of Computers

	Total Energy TJ	Electricity KWh
Total for all sectors	**6.8**	**440,000**
Electric services (utilities)	2.6	36
Computer peripheral equipment	.5	110,000
Wholesale trade	.4	17,000
Blast furnaces & steel mills	.4	14,000
Trucking & courier services, except air	.3	900
Industrial inorganic & organic chemicals	.3	9,900
Air transportation	.3	450
Paper & paperboard mills	.2	8,800
Other electronic components	.1	37,000
Semiconductors & related devices	.1	48,000

From SETAC & EIO-LCA to Hybrid



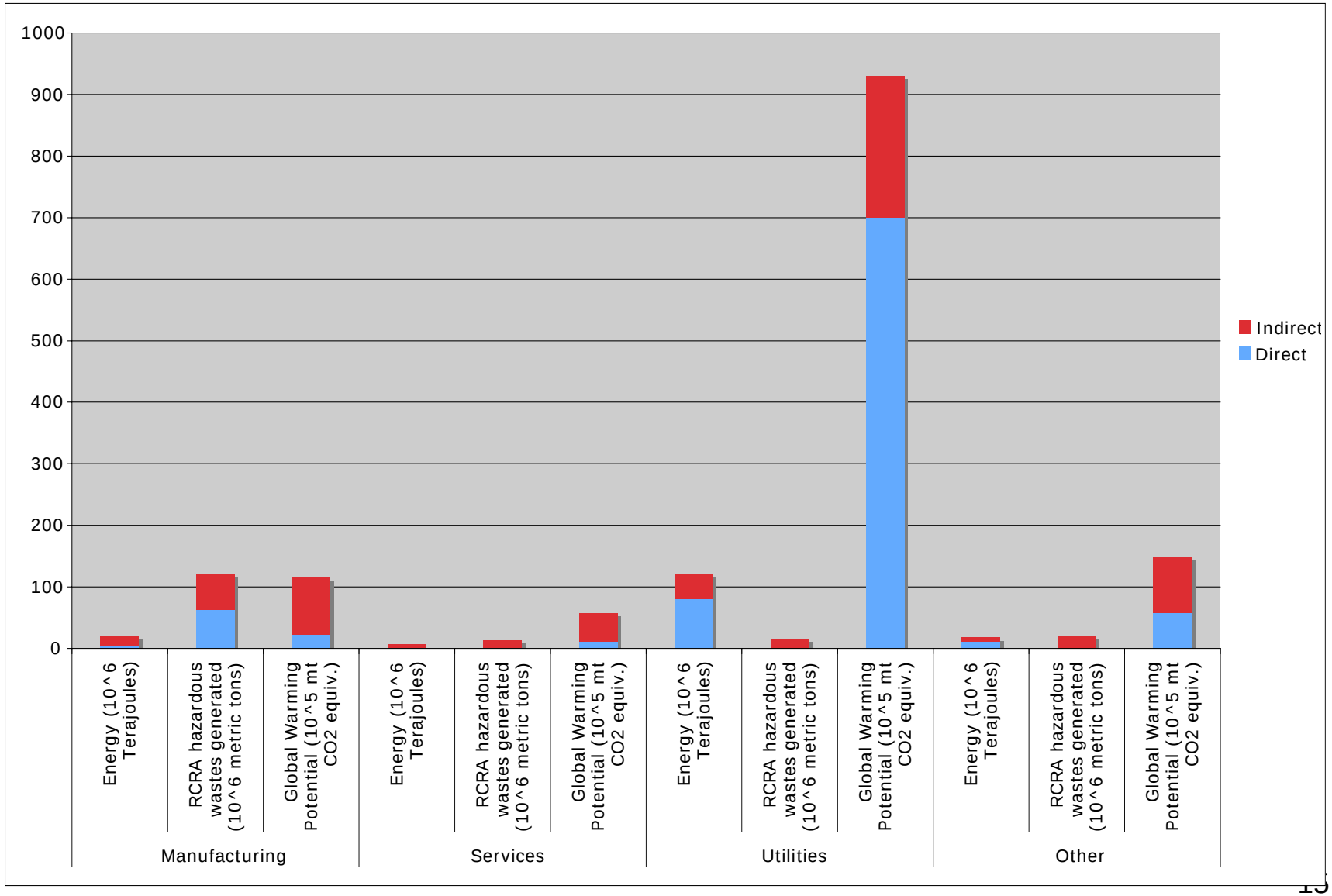
Making EIO-LCA More Useful

- Hybrid LCA: Use process analysis as inputs (composition of a car) or outputs (PM produced by air emissions)
- Technical change: Modify coefficients
- Disaggregate sectors
- Location of activity & discharges
- Materials flows: Physical units for metals
- Valuing environmental discharges
- Enterprise I-O models
- Uncertainty modeling

Some EIO-LCA Outputs

- What follows are some examples of analyses done with EIO-LCA
- First, a look at which sectors of the economy use the most resources & are most polluting

Per Million Dollars of Economic Output



For Total Sector Economic Output

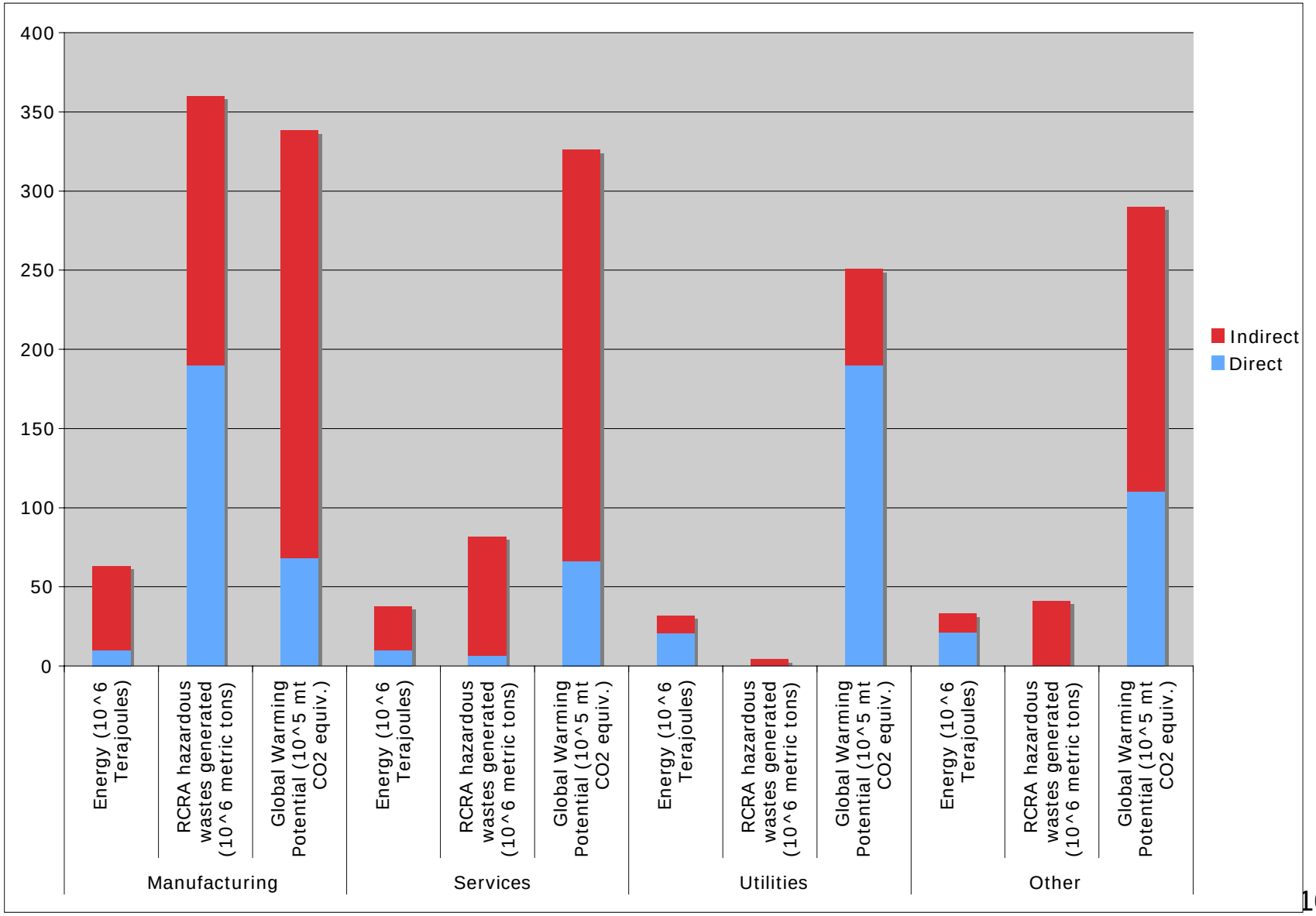
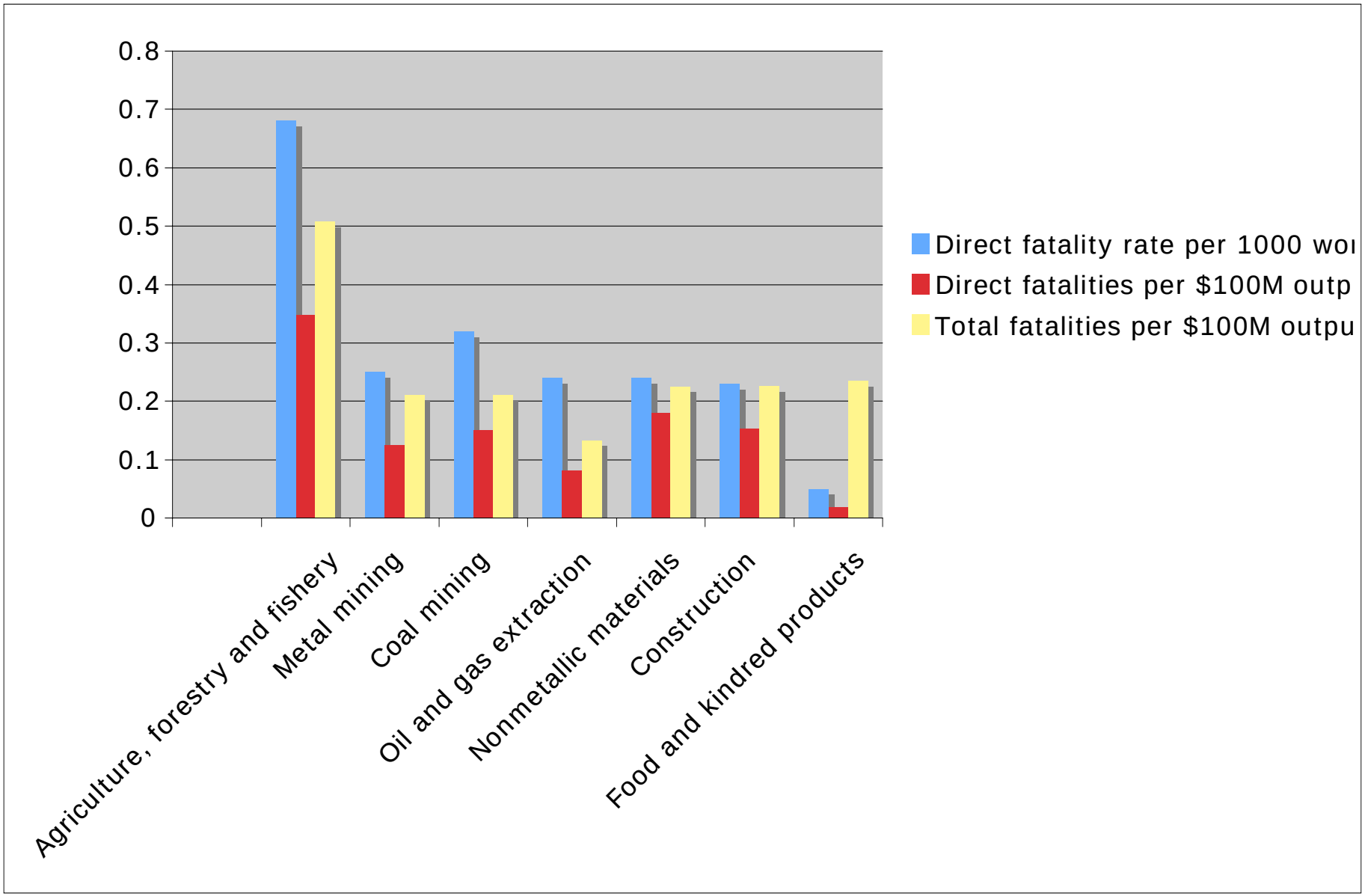


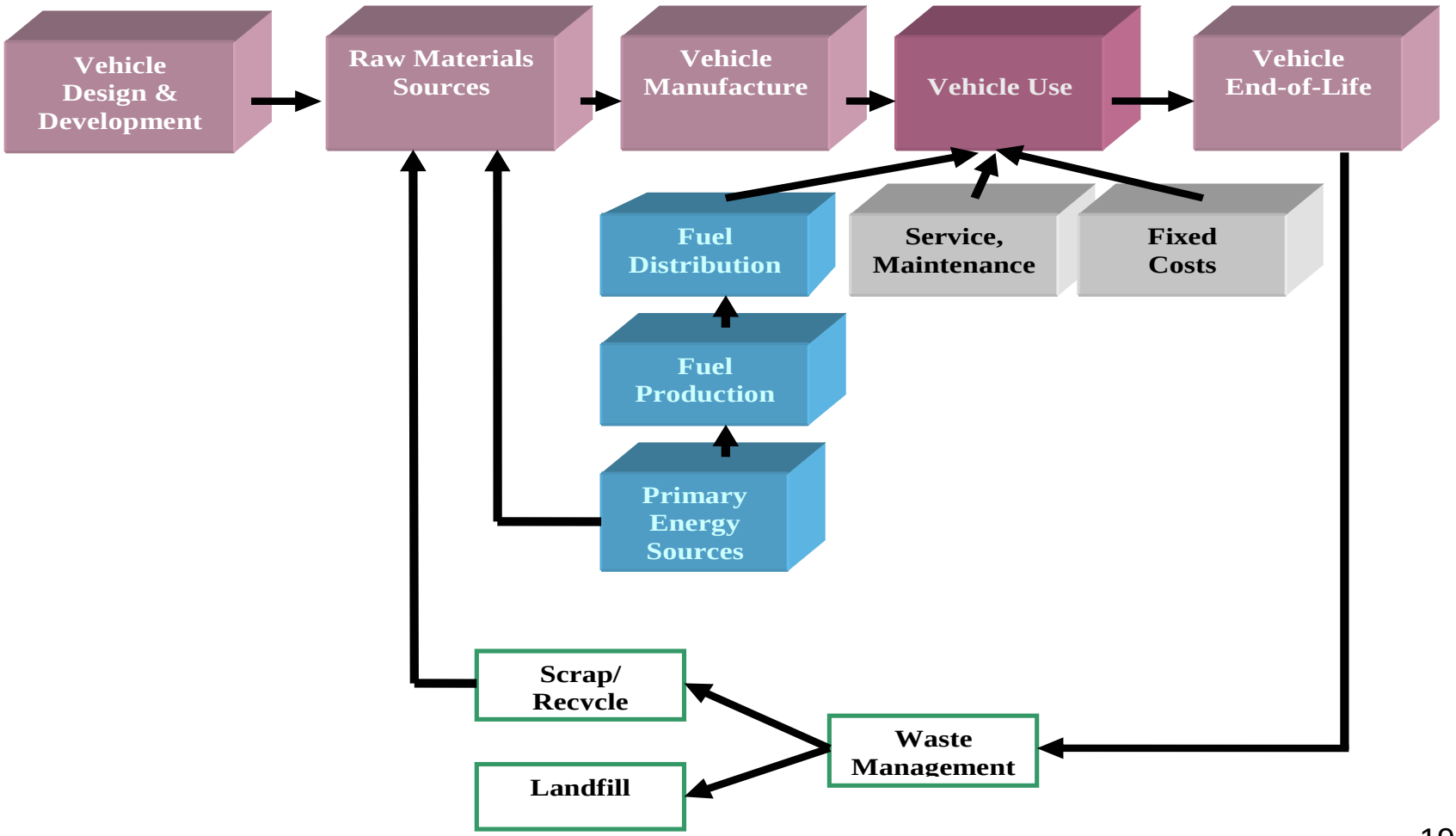
Table 15.2 # Fatality risk per $100 million of output.



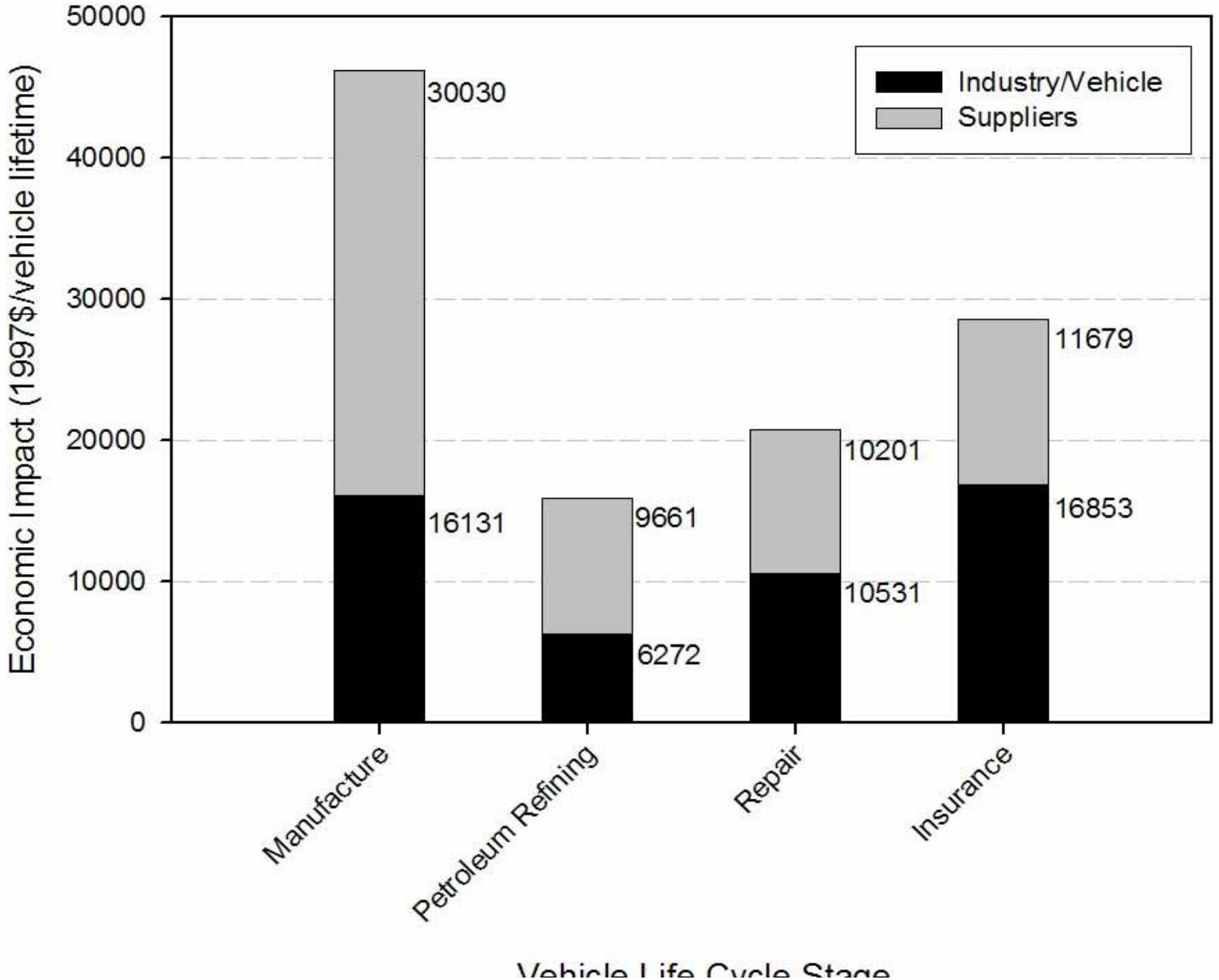
An Automobile LCA

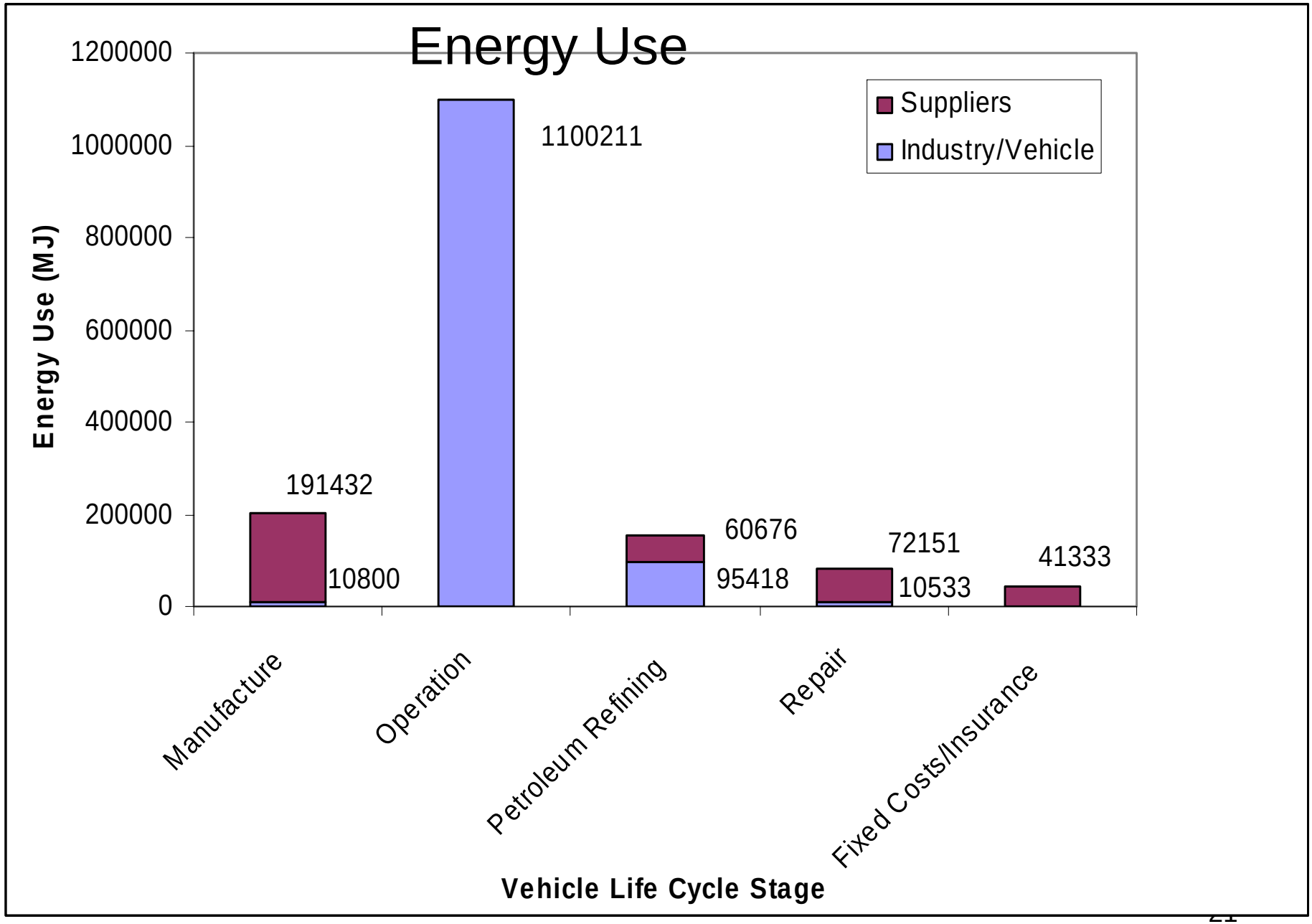
- Automobiles are 1/7 of GDP
- Use large amounts of gasoline & materials

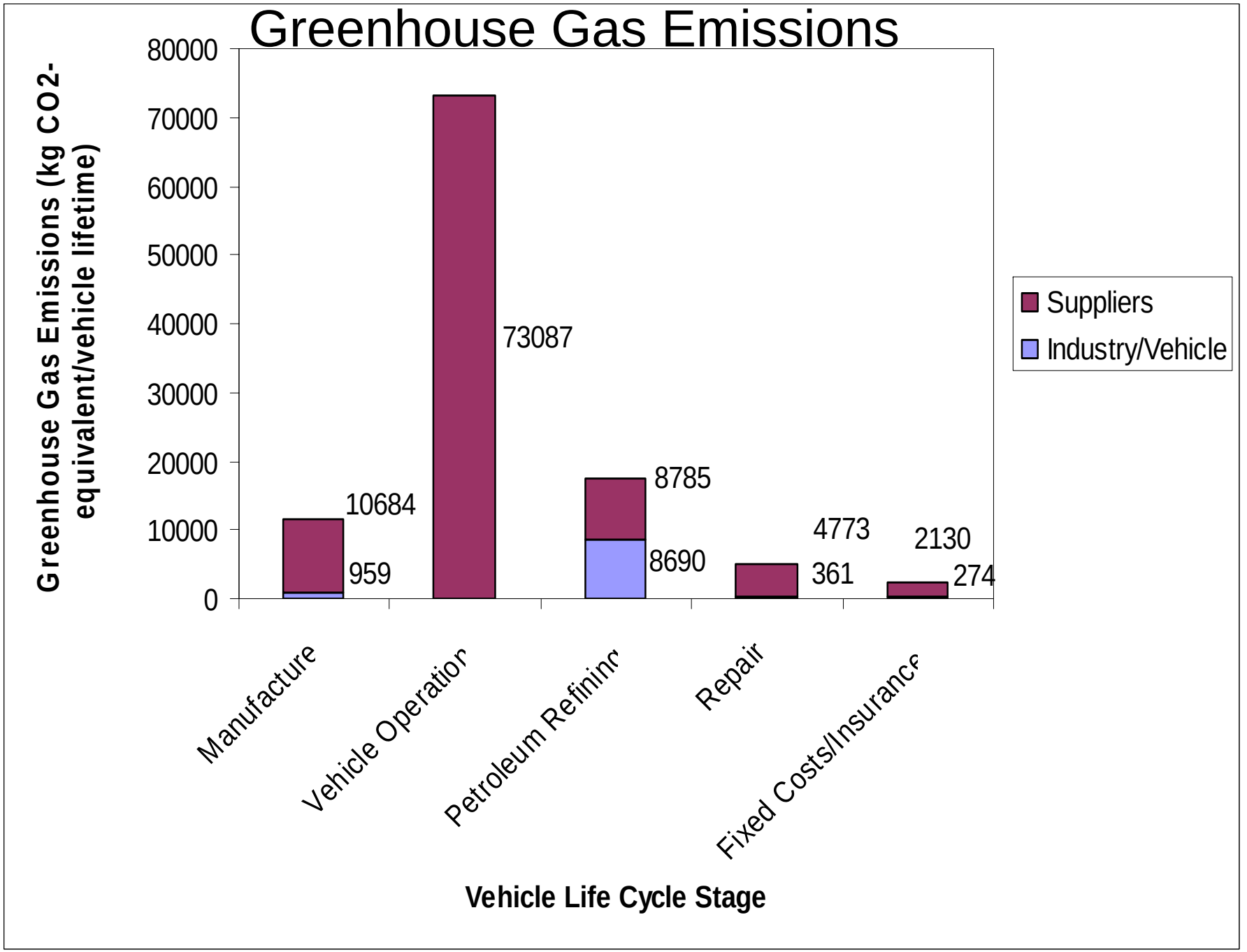
Vehicle Life Cycle



Life Cycle Assessment of a Car by Life Cycle Stage



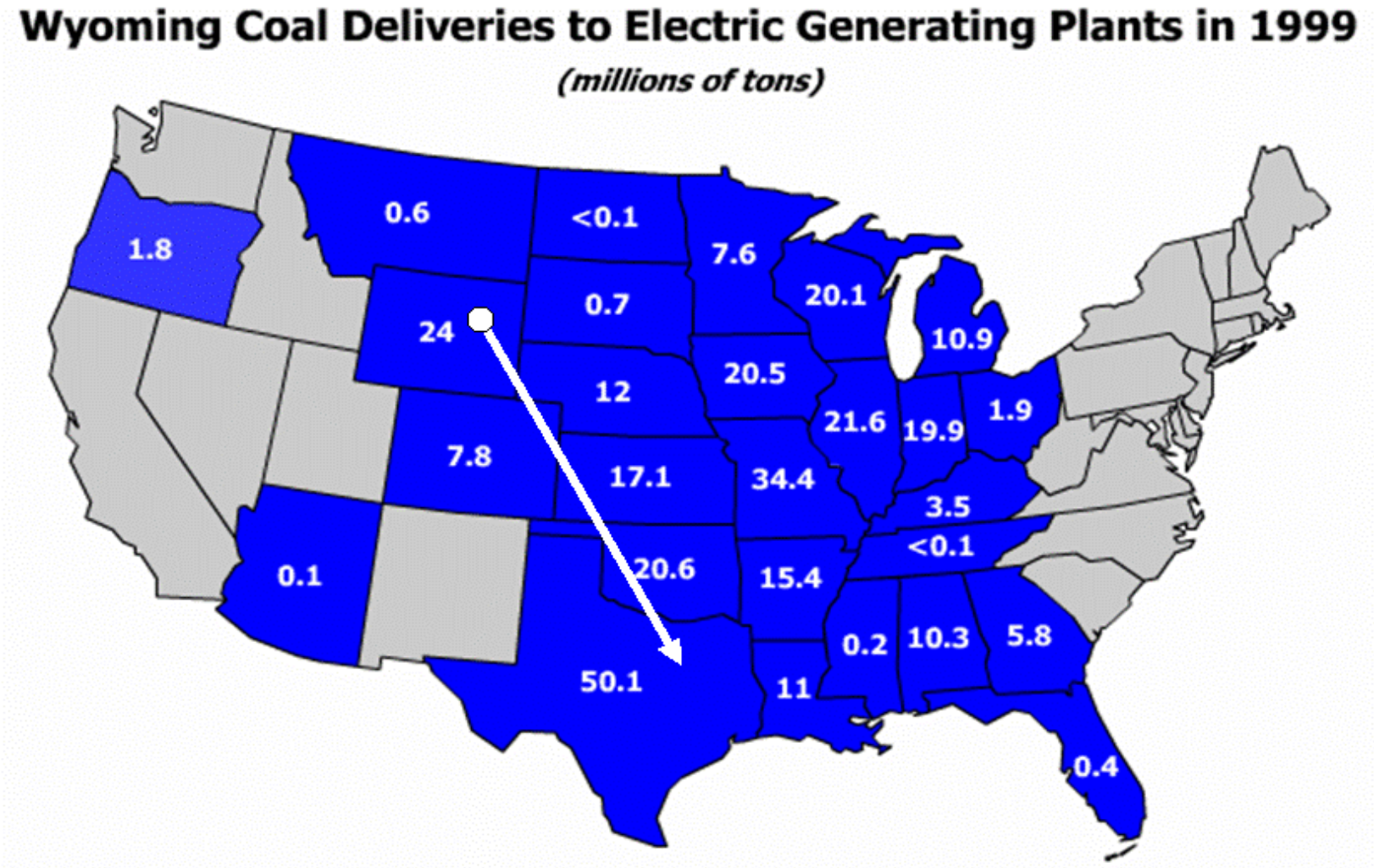

Energy Use
1200000
1000000
800000
600000
400000
200000
0
Energy Use (MJ)
Suppliers
Industry/Vehicle
191432
10800
1100211
60676
95418
72151
10533
41333
Manufacture
Operation
Petroleum Refining
Repair
Fixed Costs/Insurance
Vehicle Life Cycle Stage


Greenhouse Gas Emissions
Greenhouse Gas Emissions (kg CO2-equivalent/vehicle lifetime)
80000
70000
60000
50000
40000
30000
20000
10000
0
10684
959
73087
8785
8690
4773
361
2130
274
Suppliers
Industry/Vehicle
Manufacture
Vehicle Operation
Petroleum Refining
Repair
Fixed Costs/Insurance
Vehicle Life Cycle Stage

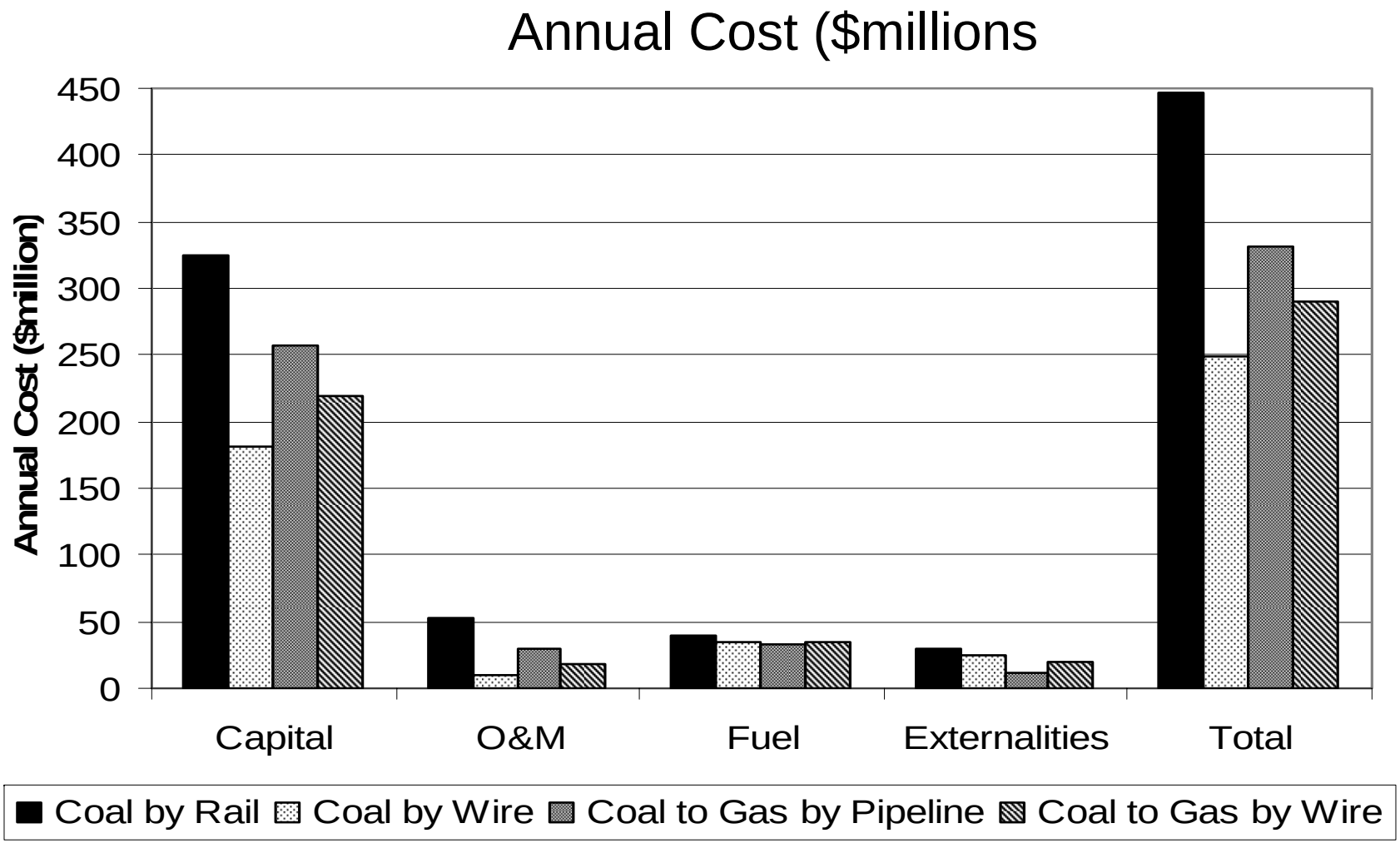
Producing Electricity in Remote Locations

- 52% of electricity is produced from coal
- Coal deposits are generally not close to electricity demand
- The Powder River Basin produces more that 1/3 of U.S. coal, 350 million tons shipped by rail up to 1,500 miles
- Should PRB coal be shipped by rail?

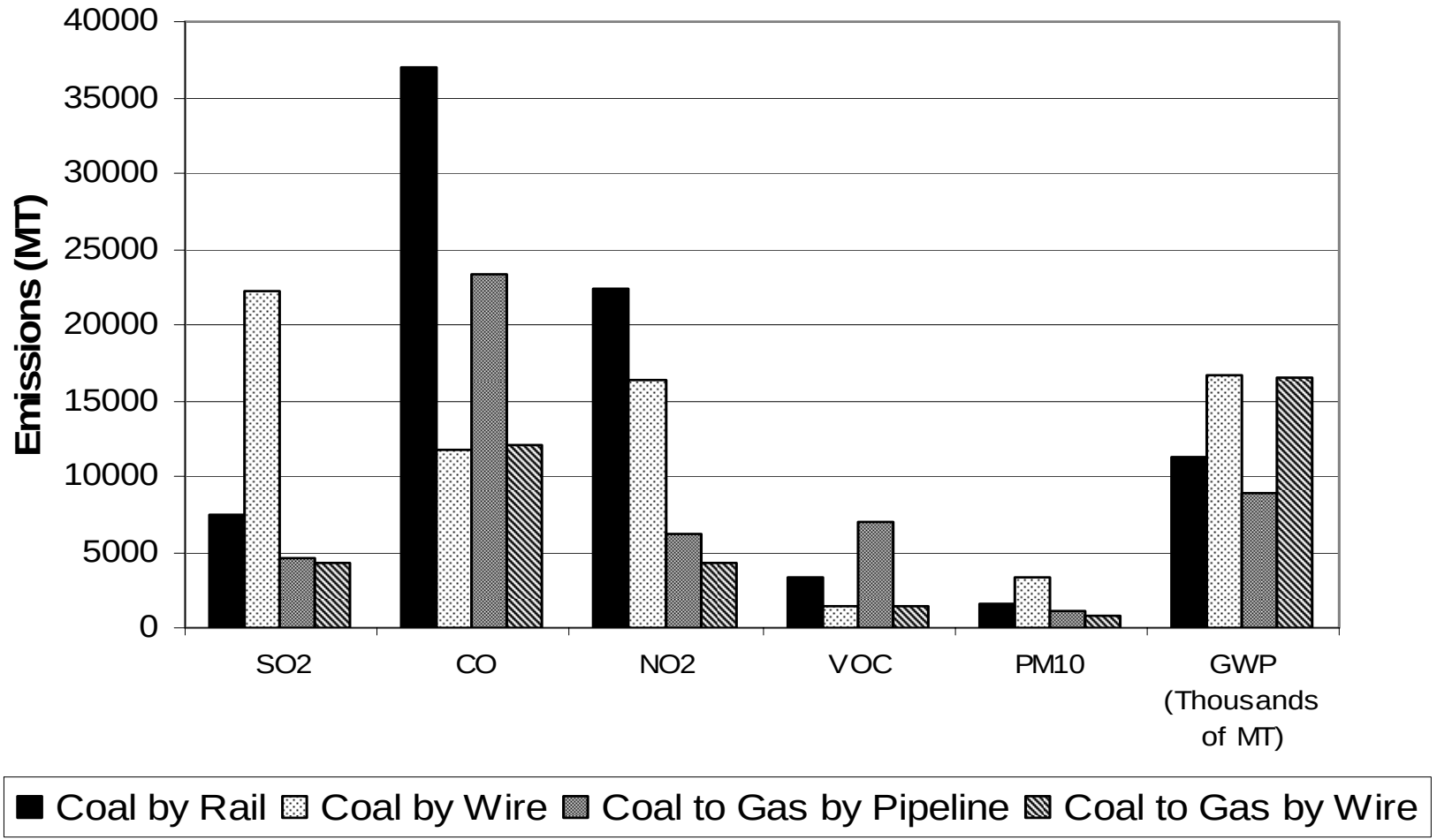
Wyoming to Texas Coal Transport



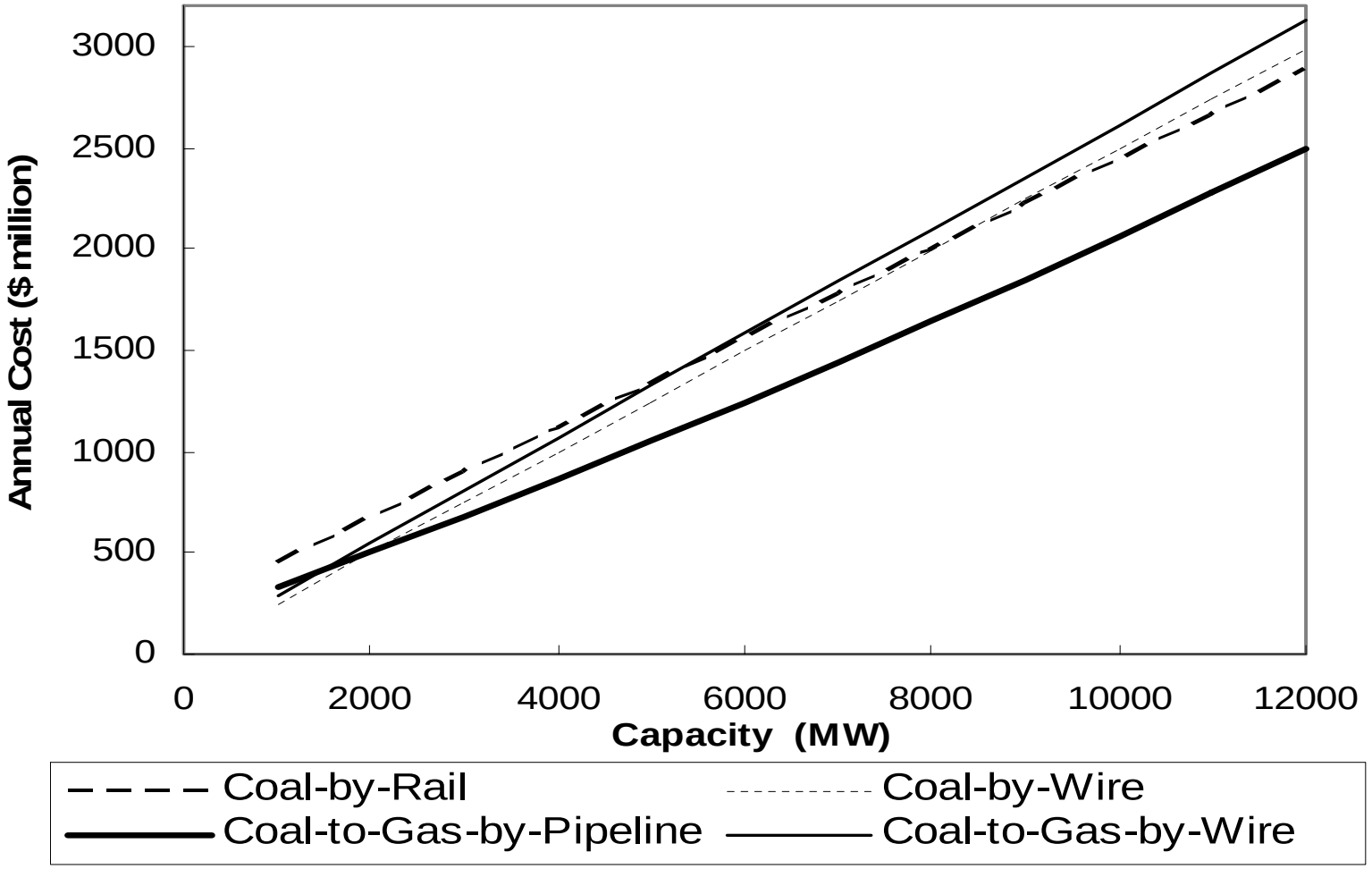
Transporting Energy from WY to Texas: All New Infrastructure



Emissions from Transporting Energy



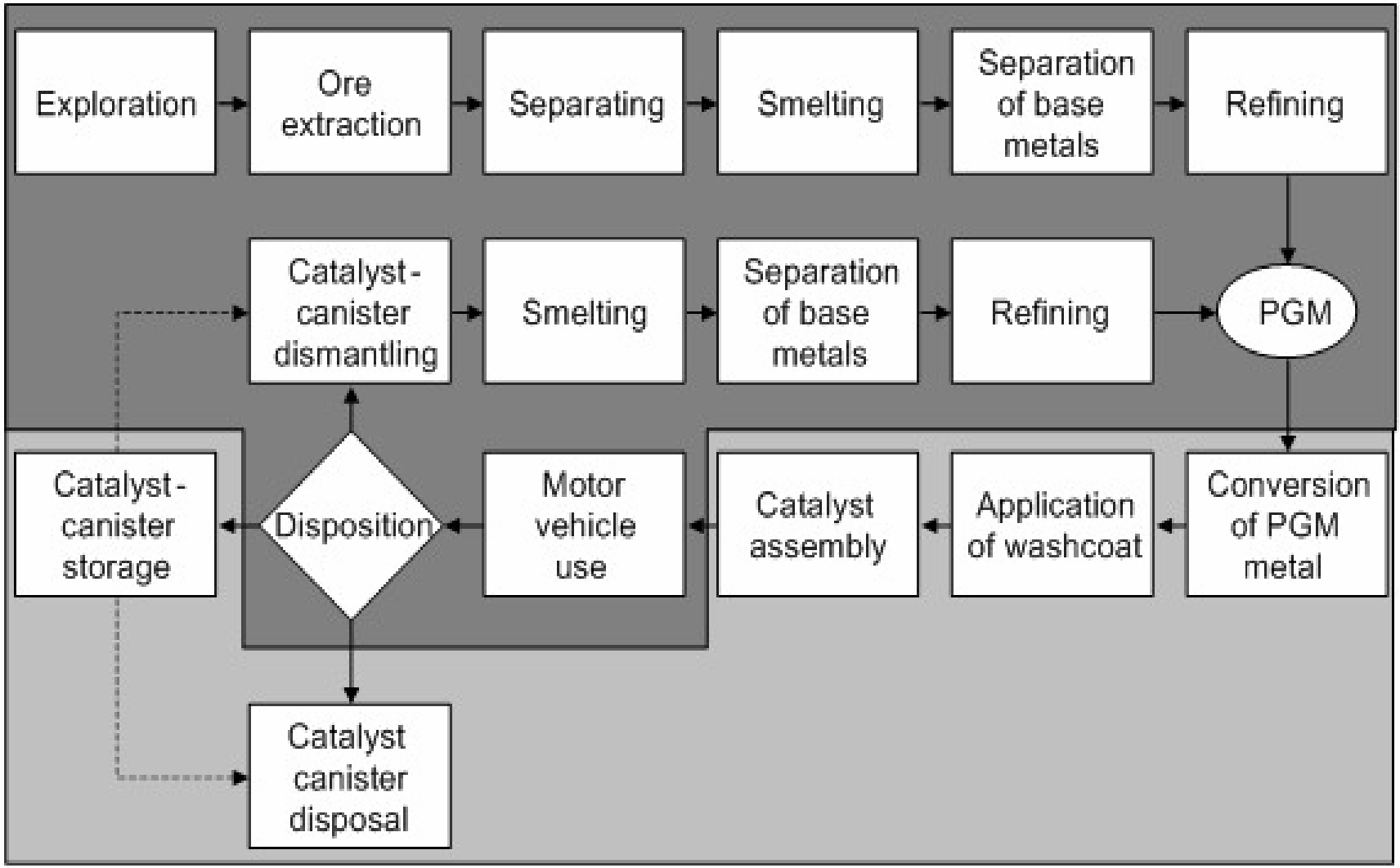
What Is Best Mode as Scale Increases? Lessons for CA



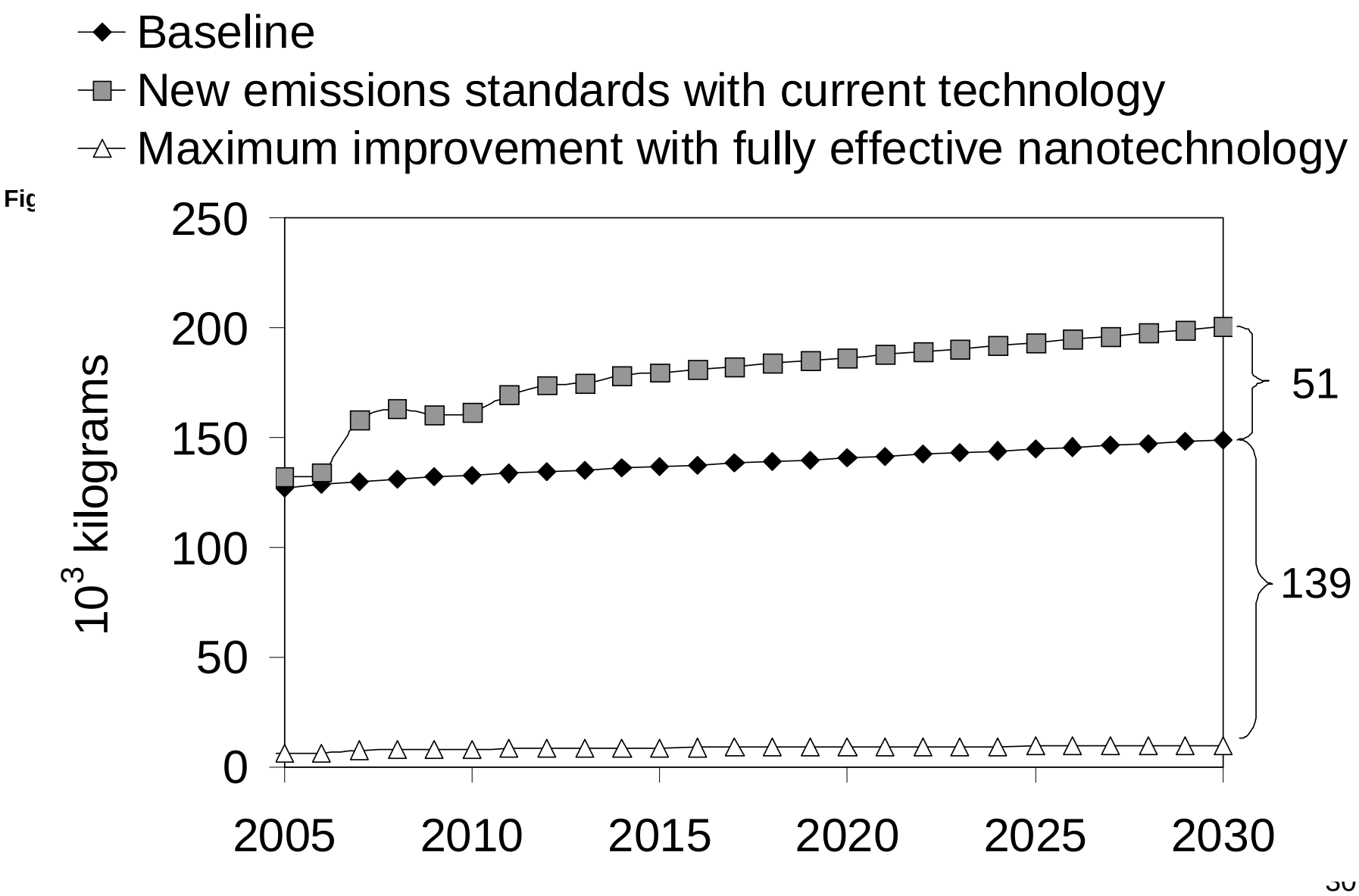
Evaluating Nanotechnogy's Potential

- The ability to manipulate atoms has the potential for tremendous gains in efficiency, material strength & other properties, lowering energy & materials use, & lowering environmental discharges
- Improving environmental quality & making the economy more sustainable

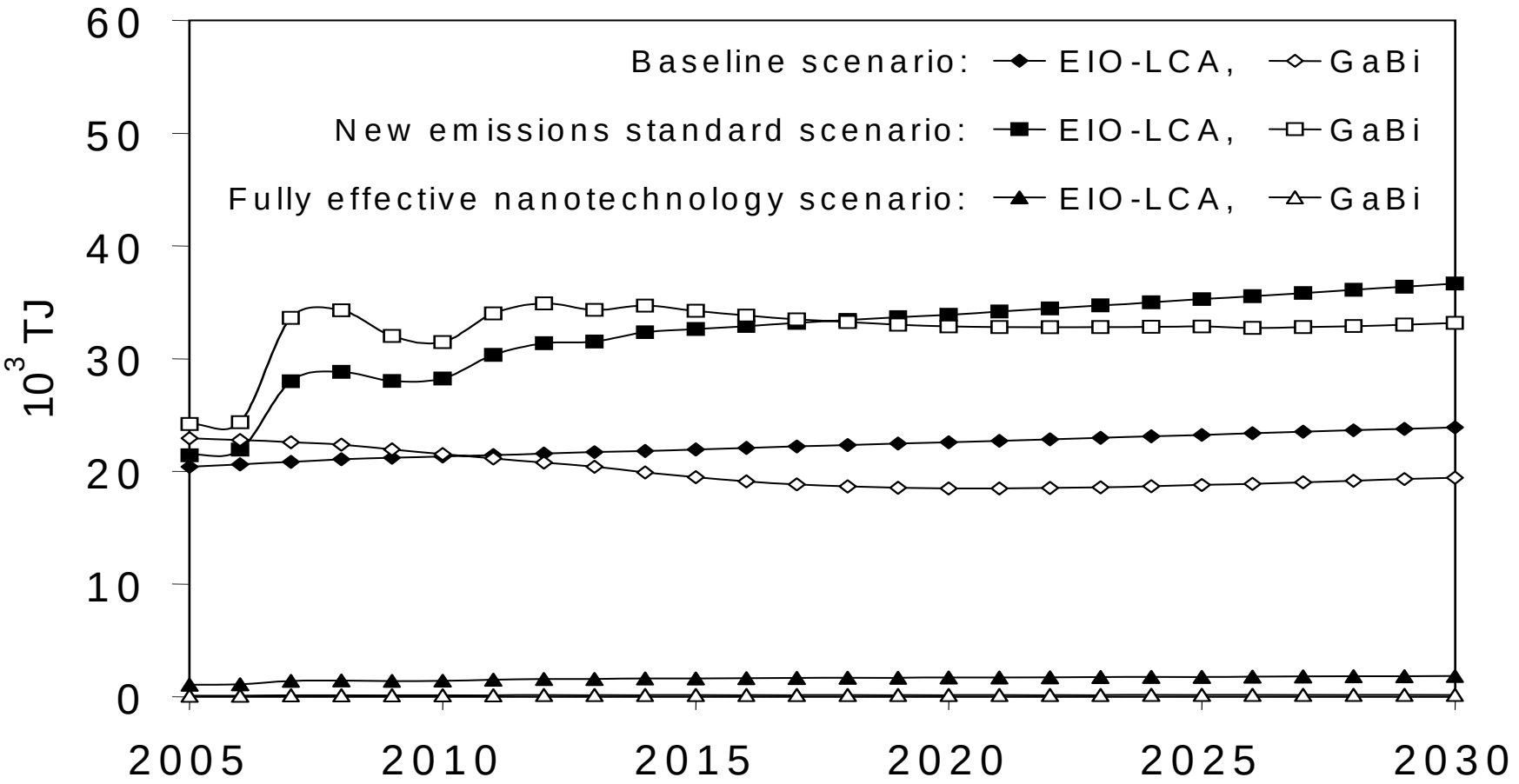
Nanotech: Improving Catalytic Converters in Cars



PGM Requirement for Cat. Converters



Estimated annual energy required to produce Platinum Group Metals with EIO-LCA & a Process Model (GaBi) for Three Scenarios

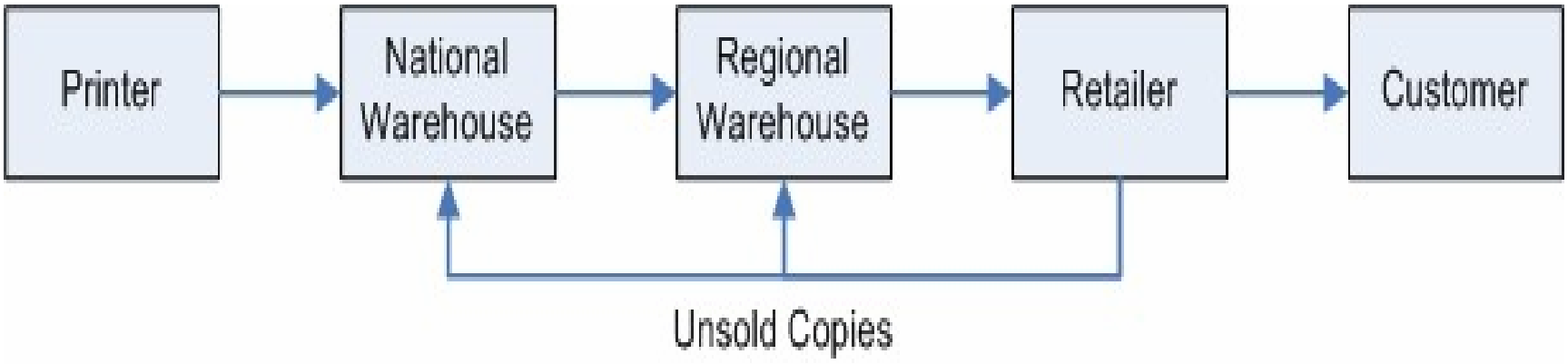


LCA for the Service Sector

- As shown above, the service sector is responsible for a large proportion of energy & materials use & discharges
- We examine whether traditional book distribution is better than E-commerce distribution

Current vs. E-Commerce Book Distribution

Traditional Book Distribution



E-Commerce Book Distribution

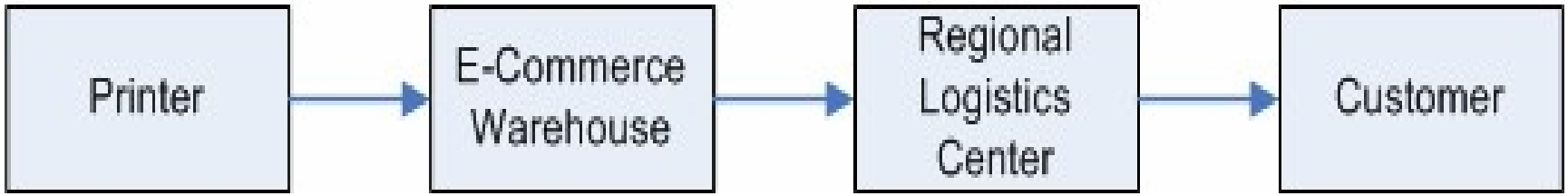
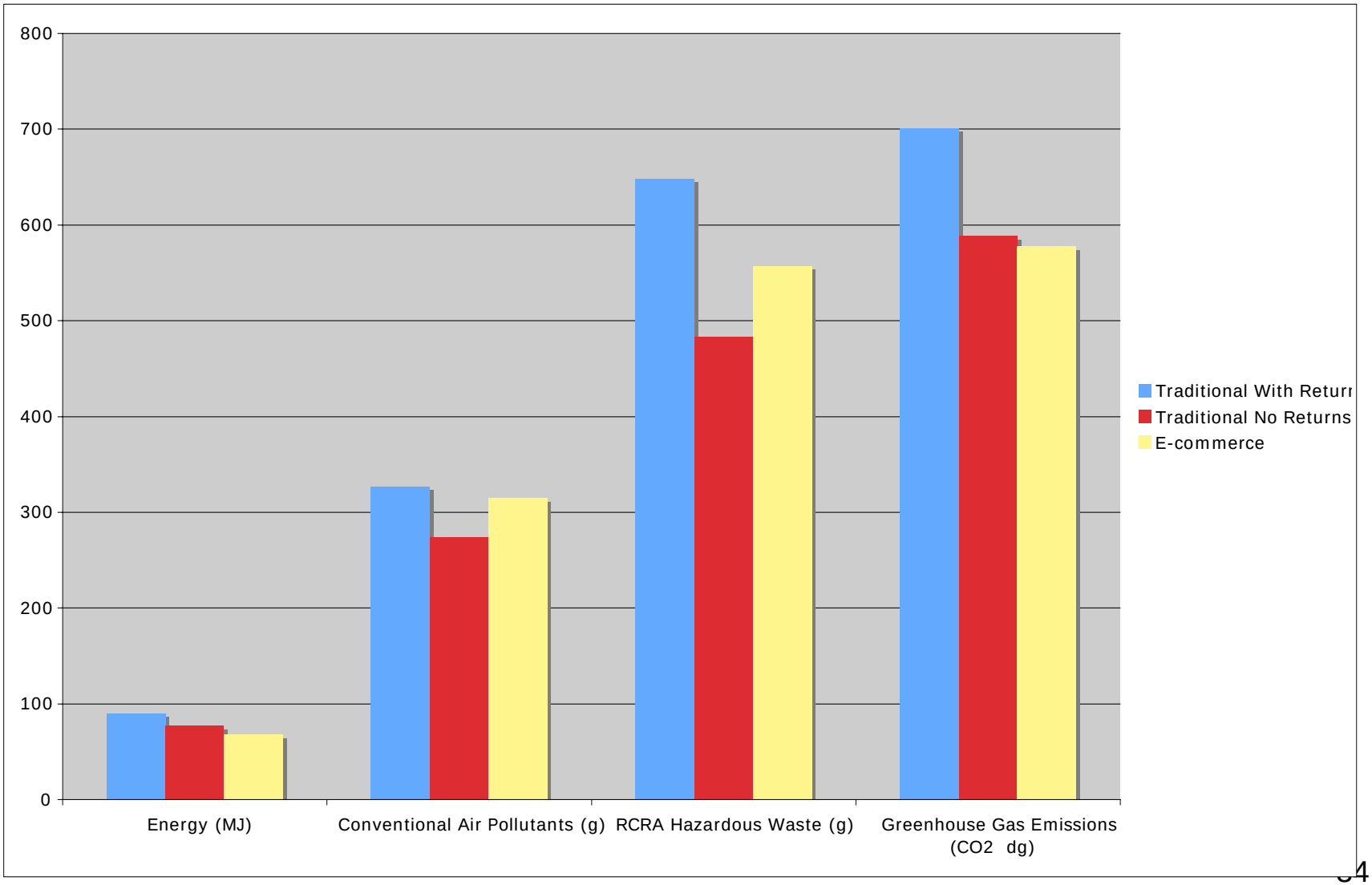


TABLE 9.8 Estimates of effects of traditional and e-commerce logistics, per book



Conclusion

- **LCA is a valuable approach for informing decisions to improve environmental quality & sustainability**
- **EIO-LCA has made LCA practical.**
- **Hybrid LCA gives as accurate an answer as you are willing to spend time & money on**
- **EIO-LCA sparked interest in I-O among non-I-O professionals: 200,000 web hits**
- **Similar models in EPA, Canada, Japan, Netherlands, Germany, etc.**

Making EIO-LCA Accessible

- www.eiolca.net makes the software available to everyone at no cost
- Offers 1992 & 1997 benchmark tables
- More than 200,000 uses since 2001

An Invitation

- Visit our web site: www.eiolca.net
- Papers at www.gdi.ce.cmu.edu
- ***Environmental Life Cycle Assessment of Goods & Services: An Input-Output Approach*** explains the method & gives many examples of how to use it. The book will be published by Resources for the Future in December 2005.
- Fliers are available or contact me at lave@cmu.edu