

Carbon Footprint Estimation

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Green Design Institute

- **Research and educational programs to develop practical pollution prevention and waste reduction technologies, methods, and tools for sustainable development. Started 1992 as university initiative.**
- **Focused on:**
 - **Interdisciplinary, systems research**
 - **Industry, agency and societal needs**
 - **Development of practical methods and tools**
 - **Educational activities**
- **Participants from:**
 - **Engineering**
 - **Economics and Business Management**
 - **Science**
 - **Architecture**
 - **Social and Decision Sciences**
 - **Computer Science/Robotics**

US Carbon Management Drivers

- California Climate Registry, Carbon Label Legislation (AB 2538), Global Warming Solutions Act of 2006 (AB 32)
- EPA Registry Initiative (HR 2764 2007): Standard due soon.
- Corporate Initiatives: Wal-mart, Tesco
- Climate Security Act (Lieberman-Warner Proposed Legislation)

Typical GHG Reporting Tiers

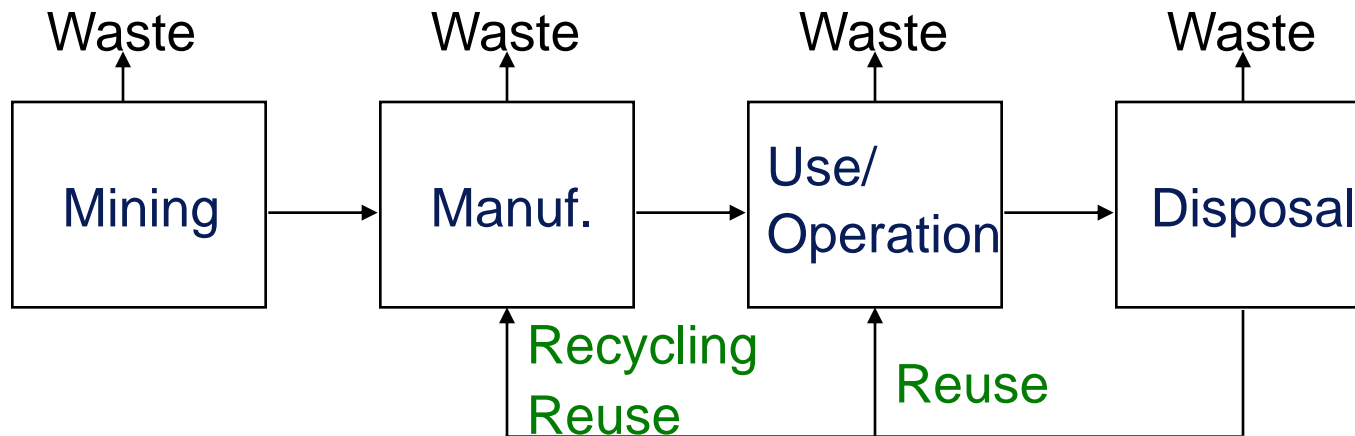
- Tier 1: Direct GHG emissions (on-site combustion, company vehicles)
- Tier 2: Purchased energy (electricity, steam) + direct emissions
- Tier 3: Indirect (supply-chain) emissions
- May or may not include non-CO2 GHG.
- Use phase of products not normally included.

Tier 1 and 2 GHG Emissions are typically small relative to Tier 3

Sector	Tier 1 (% of Tier 3)	Tier 1 + 2 (% of Tier 3)
Book Publishing	5	6
Power Generation	92	93
Average Sector	14	26

Life-Cycle Assessment (LCA)

- A concept and methodology to evaluate the environmental effects of a product or activity holistically, by analyzing the whole life cycle of a particular product, process, or activity (U.S. EPA, 1993).
- LCA 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 (ISO).



EIO-LCA: Internet Based Life Cycle Assessment

- Cradle to grave analysis
- Model developed at Carnegie Mellon in 1995
- Available on Internet since 1999
 - Only easy to use, free, complete LCA model in world
- Over 1 million uses to date, thousands of registered users
- <http://www.eiolca.net/>
- Data and model increasingly valuable, especially with carbon footprinting interest.



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Example Output: GWP \$ 1 M Water, Sewer and Pipeline Construction

Sector	Emissions (Metric Tons CO ₂ Equiv.)			
	GWP	CO ₂	CH ₄	N ₂ O
Water, sewer, & pipeline construction	387	387	0	0
Power generation and supply	124	123	0	0
Cement manufacturing	57	57	0	0
Truck transportation	56	55	0	1
Iron and steel mills	55	55	0	0
Oil and gas extraction	21	4	17	0
Waste management & remediation services	20	3	17	0
Petroleum refineries	18	18	0	0
Air transportation	9	9	0	0
Coal mining	9	1	8	0
Pipeline transportation	8	4	4	0
Total for all 491 sectors	899	829	51	8

Carbon Footprinting (CF) and Life Cycle Assessment (LCA)

- LCA considers wide range of environmental impacts, CF only GHG
- LCA is cradle-to-grave, CF is often only company specific or company plus supply chain (indirect).
- CF is a subset of LCA

Our Suggested Analysis Tiers

- Tier 1: Direct GHG emissions (on-site combustion, company vehicles)
- Tier 2: Tier 1 + Purchased energy (electricity, steam) + direct emissions
- Tier 3: Tier 1 + Indirect (supply-chain) emissions including circularities and recycle loops. Intl. or natl. border.
- Tier 4: Tier 3 + Delivery + Use + Disposal

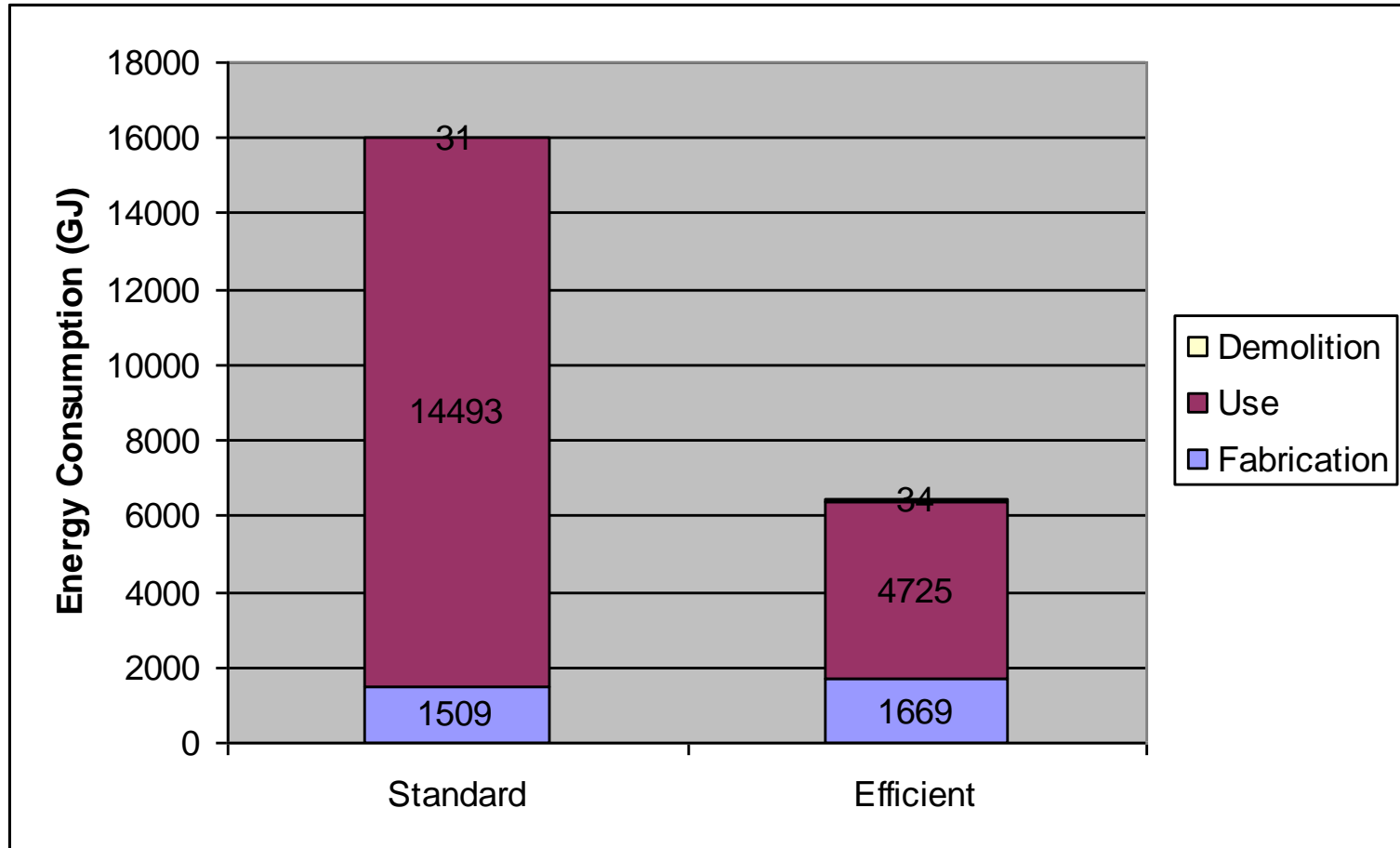
Potential Uses of Tiers

- Tier 1: Imposing direct emission regulation (tax, cap-and-trade or emission limits)
- Tier 2: Typical Carbon Footprint reporting
- Tier 3: Improved supply chain management
- Tier 4:
 - Green Product Design
 - Informing Consumer Choice

Some Examples of Products Where Different Tiers Are Critical

Use Dominates	Supply Chain Dominates	Production Dominates	Mixed or Varies
Gasoline IC Autos	Food	Power Generation	Elec- tronics
Buildings	Book Publishing	Trucking	Alternative Fuels

Example: Estimated Energy Consumption for Two Residence Designs in Pittsburgh



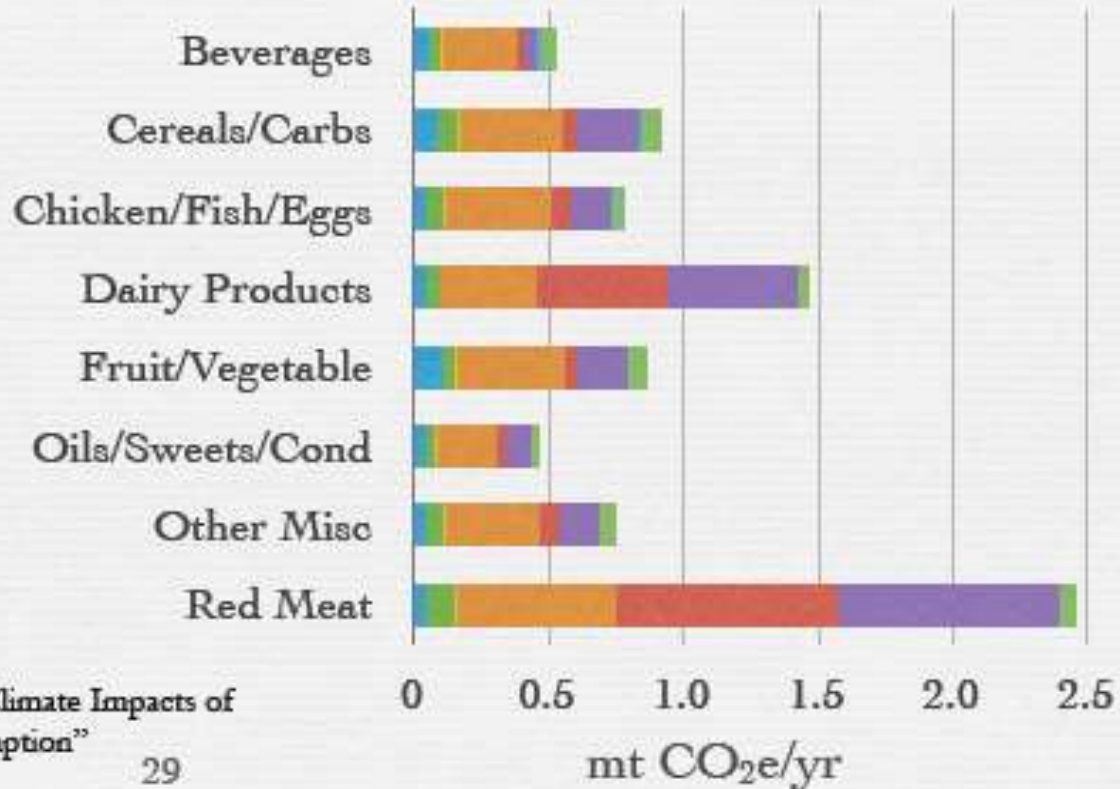
Total GWP Emissions for US Household Food

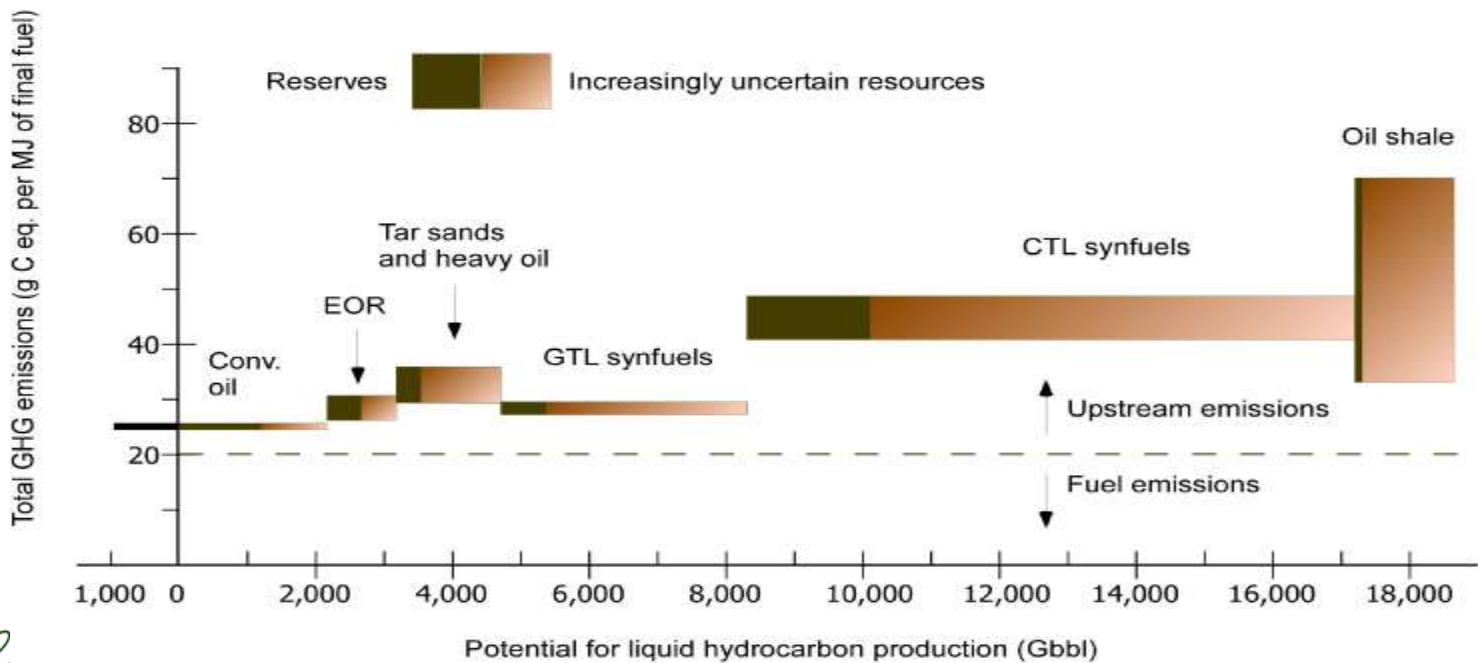
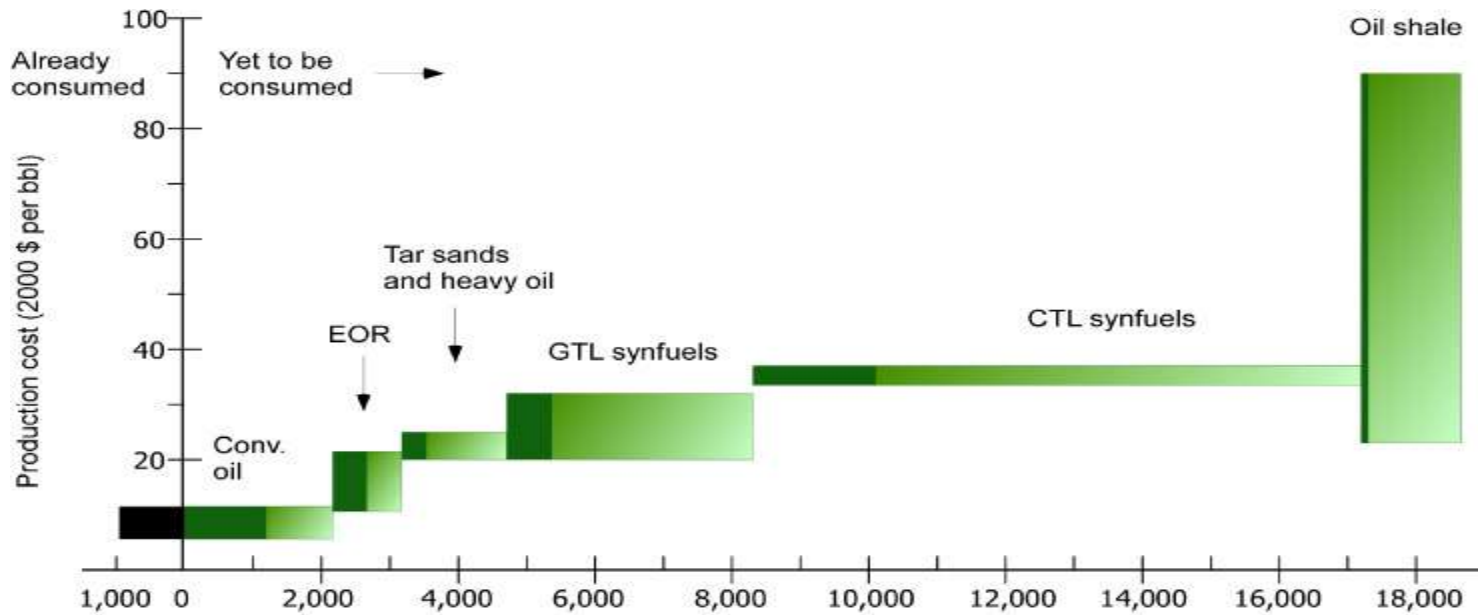
Compared to Production, transport relatively small:

11% total, 4% Delivery

CO₂ only half of impact

Non-CO₂ gases and inefficient calorie transform make red meat and dairy bad

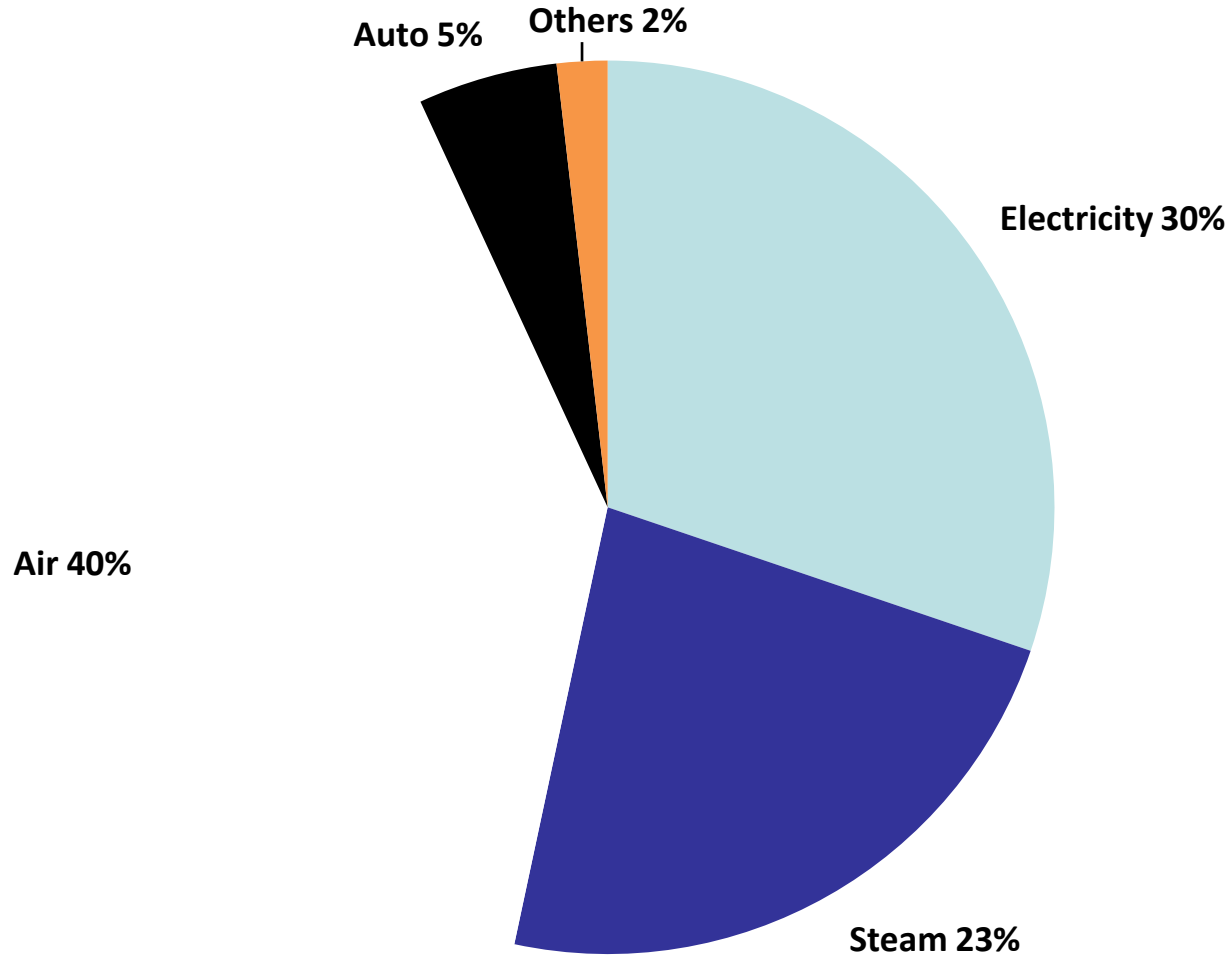




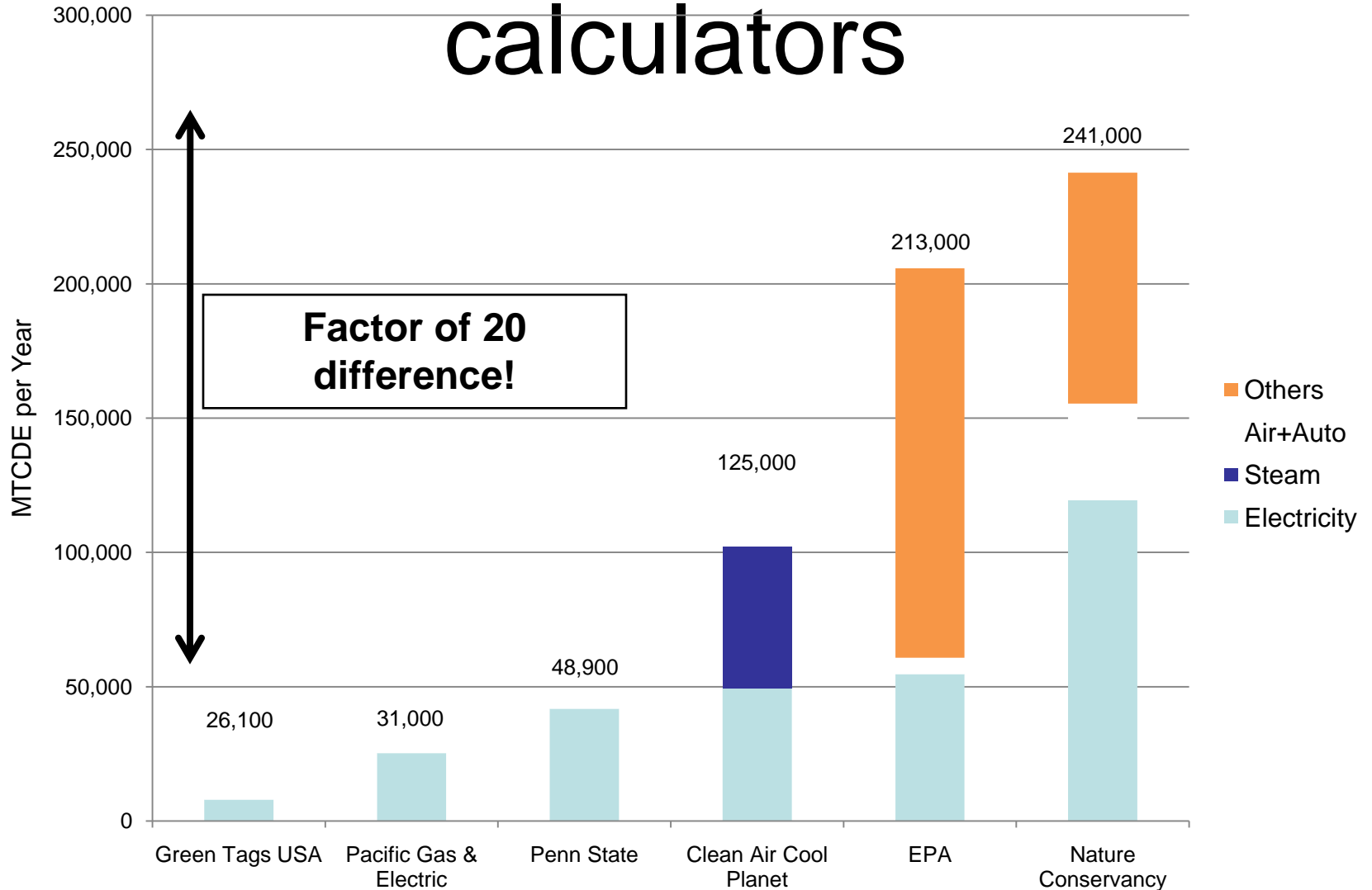
LCA/CF Criticisms / Limitations

- Data reliability and quality is often questionable.
- Models based on assumptions.
- Problem boundaries are often arbitrary.
- Scale issues - global -> local, etc.
- Uncertainty is everywhere
- Spatial and temporal issues
- Comparisons between studies difficult
- Cost and time of conducting life cycle assessment study

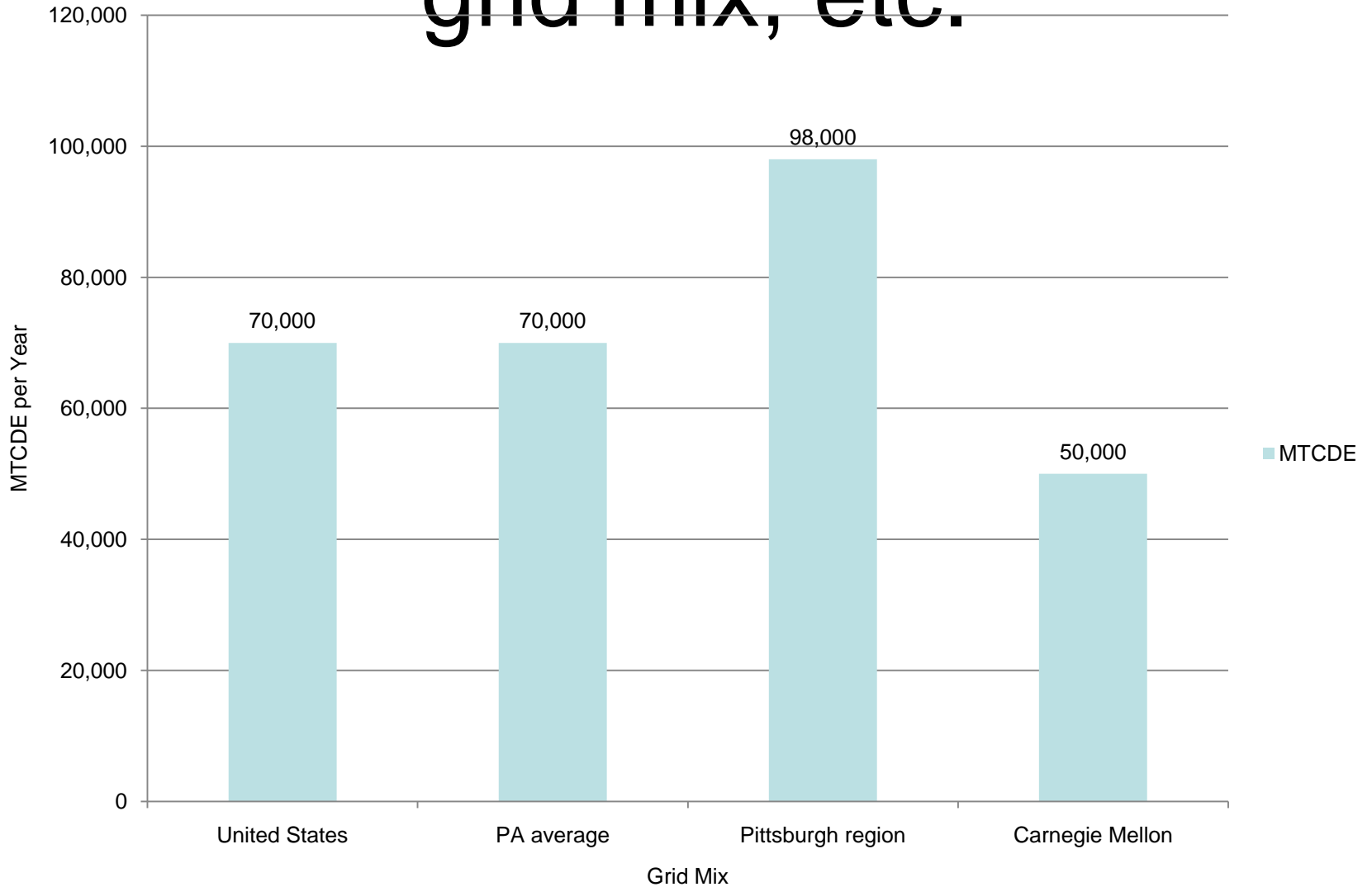
Carnegie Mellon emissions by category



Emissions vary across calculators



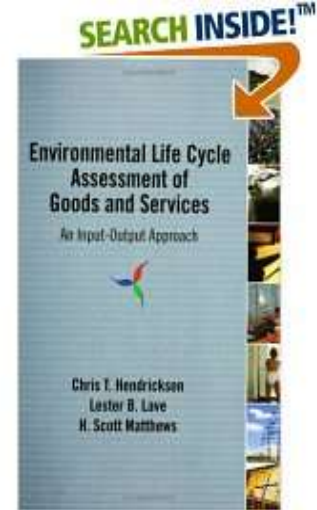
Emissions differ by electricity grid mix, etc.



Conclusion

- Boundary assumptions crucial for carbon footprinting
- Carbon footprinting conceptually similar to environmental life cycle assessment
- Carbon footprints may have different values ('tiers') for different uses

Other Resources



- www.eiolca.net
- www.gdi.ce.cmu.edu
- **Environmental Life Cycle Assessment of Goods & Services: An Input-Output Approach**
- "The Importance of Carbon Footprint Estimation Boundaries." *Environ. Sci. Technol* (August, 2008).
- "Food-Miles and the Relative Climate Impacts of Food Choices in the United States." *Environ. Sci. Technol* 42(10): 3508-3513.