Consortium on Green Design and Manufacturing
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Environmental Life-cycle Assessment of Infrastructure Systems

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September 12, 2009

Outline

- Overview of infrastructure systems
- Life-cycle assessment (LCA)
- Example
- Where is infrastructure analysis going

What is Infrastructure?

- Not just “public works!”

- Transportation (surface, air, water)
  - » roads, bridges, railroads, airports, waterways, ports, pipelines)
- Solid waste management
- Water and wastewater system
- Energy extraction, production, distribution (electricity, petroleum, etc
- Telecommunications (hard-wired and wireless services)
- Internet

- Other definitions possible

Characteristics of Infrastructure Systems

- Products and processes
- Manufacturing and service
- Long service lifetimes
- Slower physical and functional obsolescence compared to industrial products
- Large, complicated, in the public eye
- Decisions have significant economic, environmental and social consequences

What Will Influence Growth of Infrastructure?

- Growth in (primarily urban) population
  - » 6.1 billion people in 2001, 7 billion projected for 2030
  - » 95% of growth projected in “developing countries”
- Growth in “middle class”
  - » about 2 billion people today
  - » Growing in China (now ~50M) and India
- Water shortages
  - » projected to affect 3 billion people by 2015
- Longer life span, but aging population

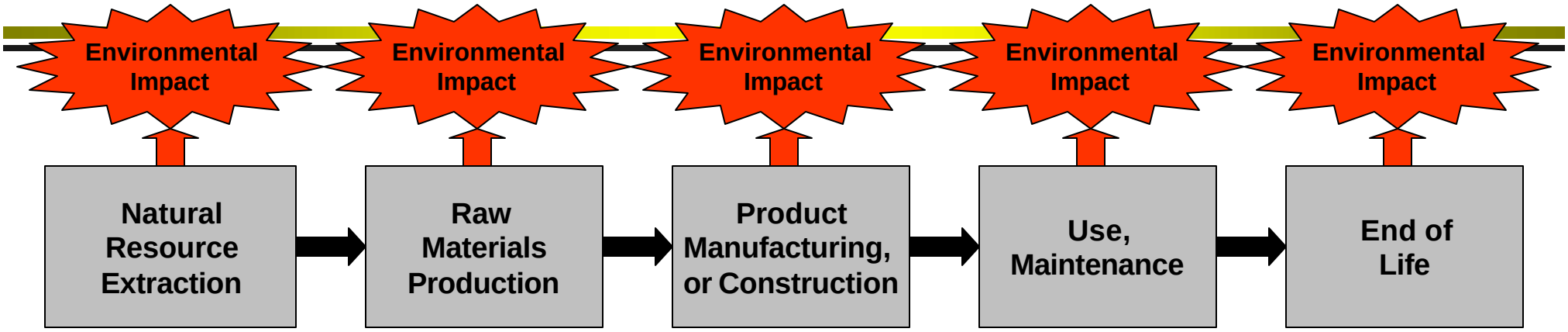
www.nepszabadsag.hu, January 20, 2

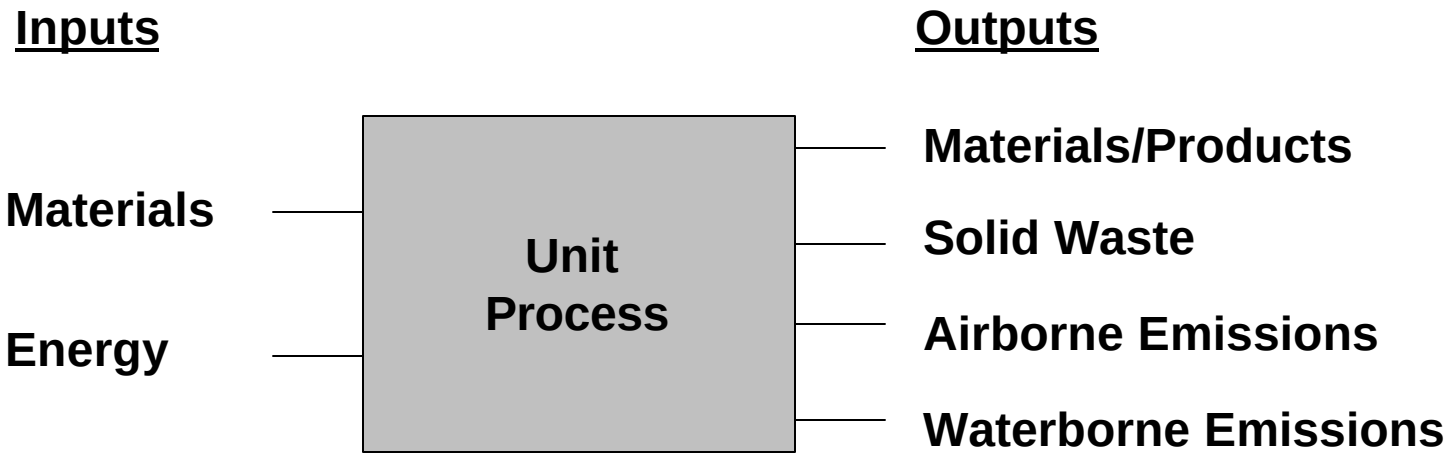
A Few Questions…

- Is high-speed rail more environmentally efficient than flying or driving?
- Should we build concrete or steel bridge designs?
- Should roadways be built to follow natural topography or utilize cuts, fills and tunnels?
- Does centralized or decentralized waste water treatment have a lower energy need?
- What are the life-cycle environmental emissions of the U.S. telecommunications system?
- Should we build water reservoirs on a hill or on flatland?
- Is solar electricity more environmentally friendly than wind electricity?

The Principles are Critical: Life-Cycle Thinking and the Precautionary Principle

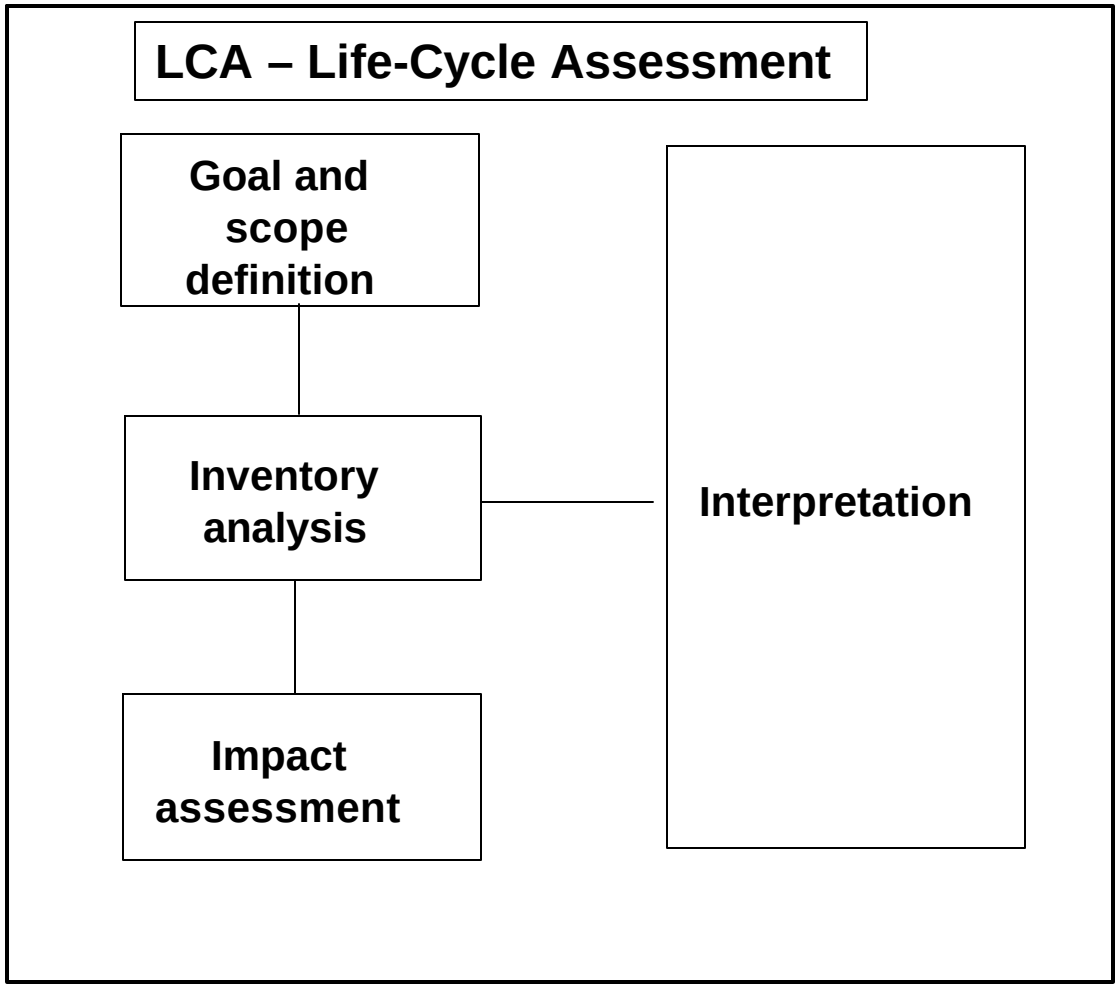
Life-cycle Assessment (LCA)





Methodology for Life-Cycle Assessment (LCA)

Following the guidelines of ISO 14040



Direct applications:

* Product development
* Product improvement
* Strategic planning
* Public policy making
* Marketing
* Other

Passenger Transportation

Problem Statement

Why do we care about emissions from transportation:

- Transportation contribution to pollution (2003)
  - » U.S. energy consumption: 104 EJ
  - » Transportation consumption: 28 EJ
    - – Passenger: 19 EJ (~ 20% total U.S.)
    - – Freight: 10 EJ (~ 10% total U.S.)
  - » World energy consumption: 449 EJ
- 25% of U.S. Population lives in regions that do not meet air quality standards for 1 or more of the criteria air pollutants
  - » 20% of land within 500m of a paved road

What problems exist in current evaluation methodology:

- Human health effects, environmental effects, and policy are typically evaluated from vehicle tailpipe performance factors
- To appropriately mitigate exposure, life cycle impacts must be considered in the infrastructures, vehicles, and fuels required to support each mode

Data Sources:

1. Davis, Diegel – Transportation Energy Data Book 25 – Tables 2.1 and 2.10
2. Nazaroff, W., Alavarez-Cohen, L., (2001), Environmental Engineering Science, Wiley and Sons, Inc., New York, NY
3. National Geographic News, “Human Footprint Seen on 83% of Earth’s Land

Emissions and Policy

- Policy is formed from tailpipe numbers
  - » Lead & sulfur removal, CAFE
- Fuel mixture targets
  - » MTBE
  - » Ethanol
- Vehicle exhaust
  - » Electric vehicles
  - » Hydrogen economy

Current Emission Considerations			
	Infrastructure	Vehicles	Fuels
Design			
Production			
Use		X	
End-of-Life			

Research Goals

- Life-cycle Inventory of 5 modes
  - » Auto, Bus, Heavy Rail, Light Rail, Air
  - » Evaluate infrastructure, vehicles, fuels
  - » Functional unit: effect per vehicle/mi
  - » Inventory
    - – Energy: Electricity and Fuels
    - – CAP: SO_2, CO, NO_X, VOC, PM, Lead
    - – GHG: CH_4, CO_2, N_2O





Photo sources:

1. http://www.atkinsglobal.com, 2. http://www.lightrailnow.org, 3. http://www.baycrossings.com

4. http://media.nasaexplores.com/ , 5. http://bard.wr.usgs.gov

Systems Evaluated

Onroad

Sedan

SUV

Pickup

Urban Bus

Rail

BART

Boston Green Line

Caltrain

Muni Metro

Air

Boeing 737

Boeing 747

Embraer 145

Components Included

Grouping	Onroad	Rail	Air
Vehicles			
Manufacturing	• Vehicle manufacturing	• Train manufacturing	• Aircraft manufacturing • Engine manufacturing
Active Operation	• Running • Cold Start • Brake Wear • Tire Wear • Idling	• Propulsion	• Take off • Climb out • Cruise • Approach
Inactive Operation	• Evaporative Losses	• Idling • Auxiliaries	• APU operation • Startup • Taxi out • Taxi in
Maintenance	• Vehicle maintenance • Tire replacement	• Train maintenance • Train cleaning • Flooring replacement	• Aircraft maintenance • Engine maintenance
Insurance	• Vehicle liability	• Crew health and benefits • Train liability	• Crew health and benefits • Aircraft liability
Infrastructure			
Construction	• Roadway construction	• Station construction • Track construction	• Airport construction • Runway/Taxiway/Tarmac construction
Operation	• Roadway lighting • Herbicide spraying • Roadway salting	• Station lighting • Escalators • Train control • Station parking lighting • Station miscellaneous	• Runway lighting • Deicing fluid production • GSE operation
Maintenance	• Roadway maintenance	• Station maintenance • Station cleaning	• Airport maintenance
Parking	• Roadside, surface lot, and parking garage parking	• Station parking	• Airport parking
Insurance		• Non-crew health insurance and benefits • Infrastructure liability insurance	• Non-crew health and benefits • Infrastructure liability
Fuels			
Production	• Gasoline and diesel fuel refining and distribution	• Train electricity production • Train electricity T&D losses • Infrastructure electricity production • Infrastructure electricity T&D losses	• Jet fuel refining and distribution

Normalization Biases

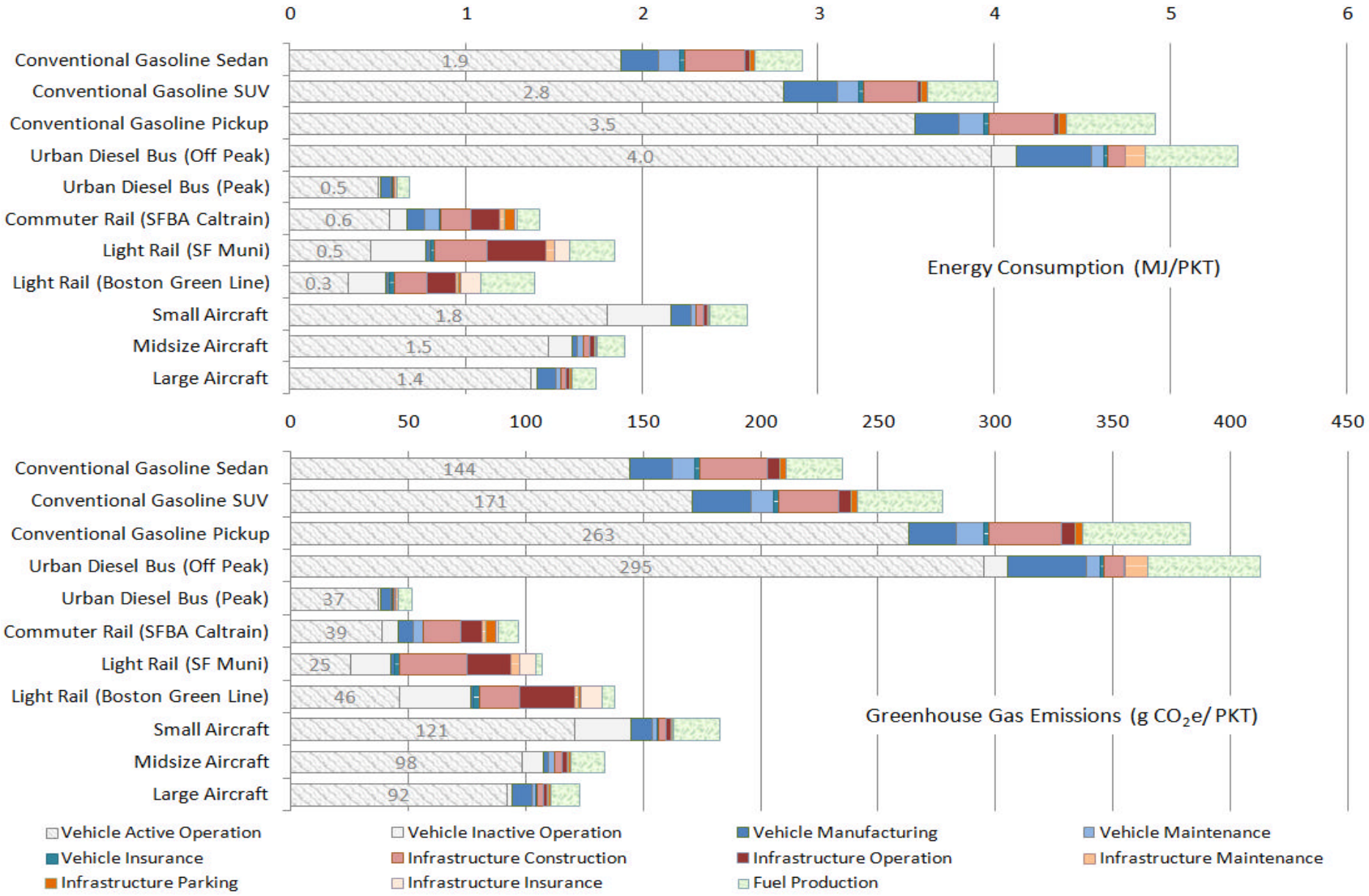
Is there such thing as an average bus?

Photo sources:

O'Connor, A.; Bowley, G. *Tornado Hits Brooklyn; Subway Back in Service*; New York Times, 8/8/2007

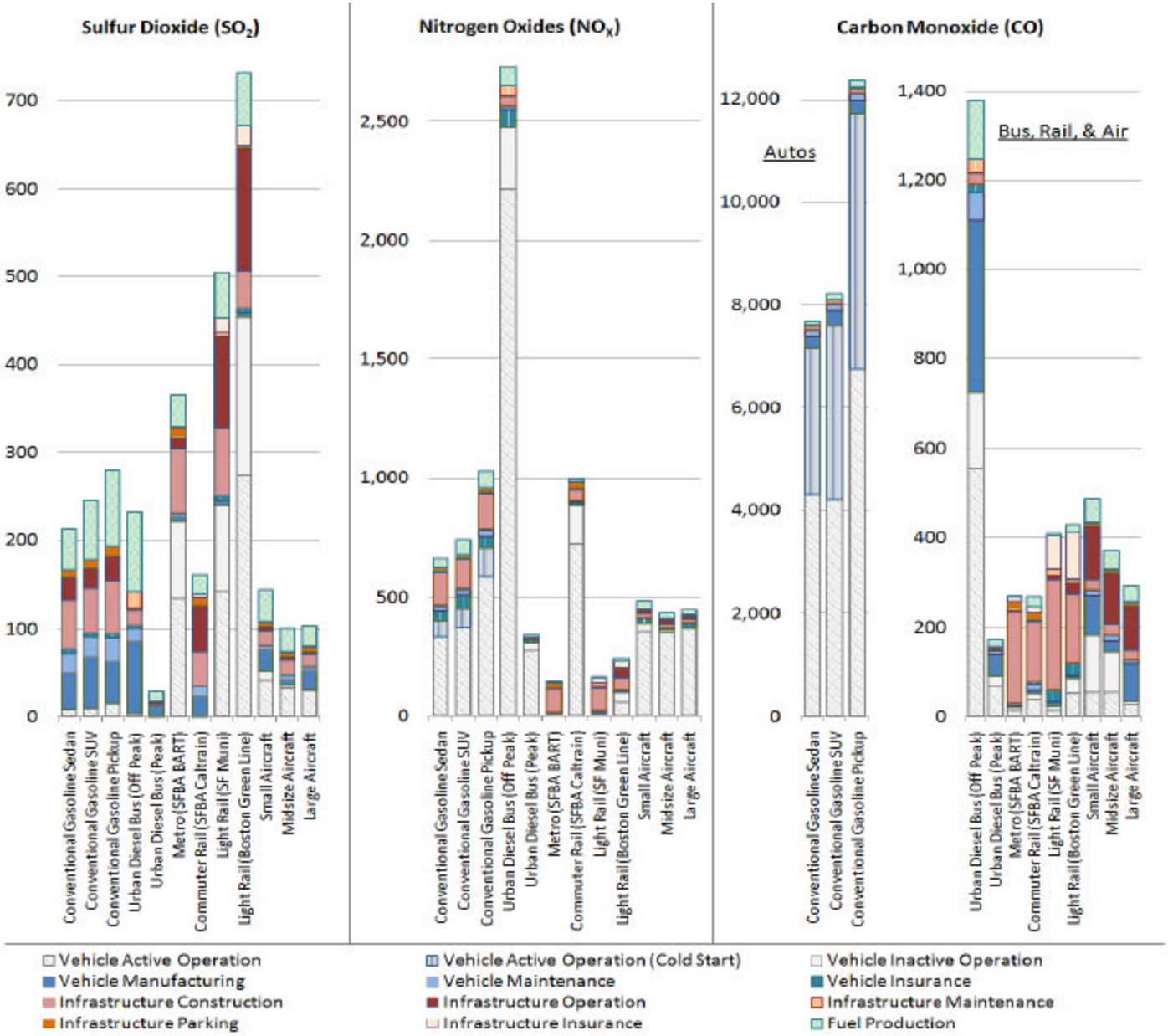
http://farm1.static.flickr.com/44/119399942_545dec30b6.jpg

Energy and Greenhouse Gas Emissions



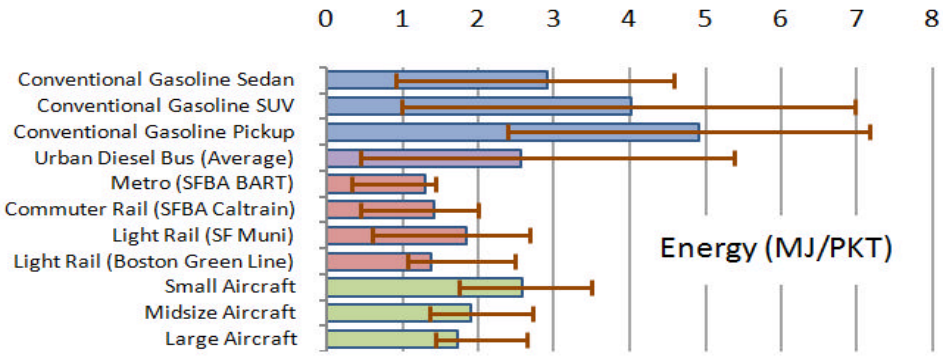
Mikhail Chester and Arpad Horvath; Environmental assessment of passenger transportation should include infrastructure and supply chains; Environmental Research Letters 2009; Available online at http://dx.doi.org/10.1088/1748-9326/4/2/024008.

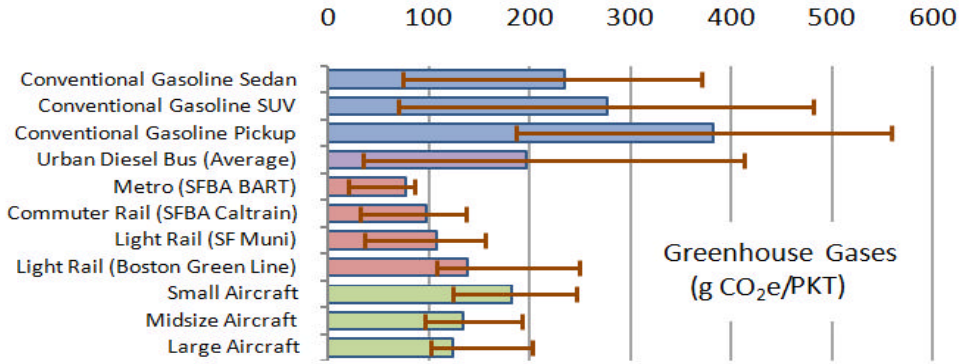
Criteria Air Pollutant Emissions

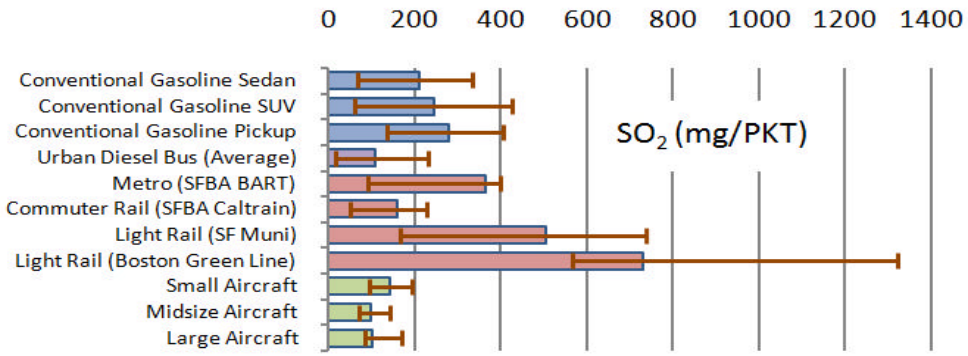


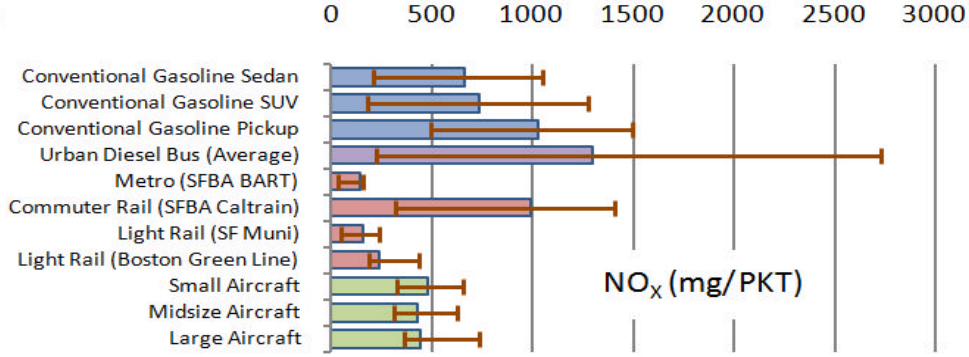
Mikhail Chester and Arpad Horvath; Environmental assessment of passenger transportation should include infrastructure and supply chains; Environmental Research Letters 2009; Available online at http://dx.doi.org/10.1088/1748-9326/4/2/024008.

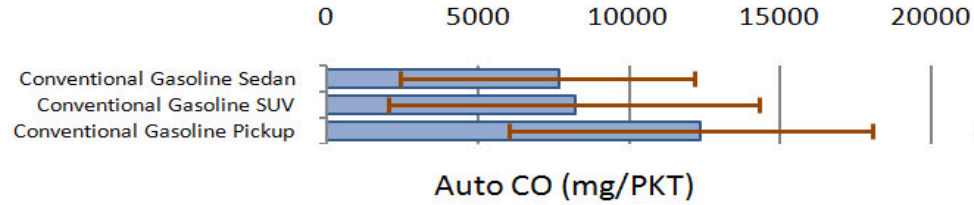
Sensitivity to Passenger Occupancy

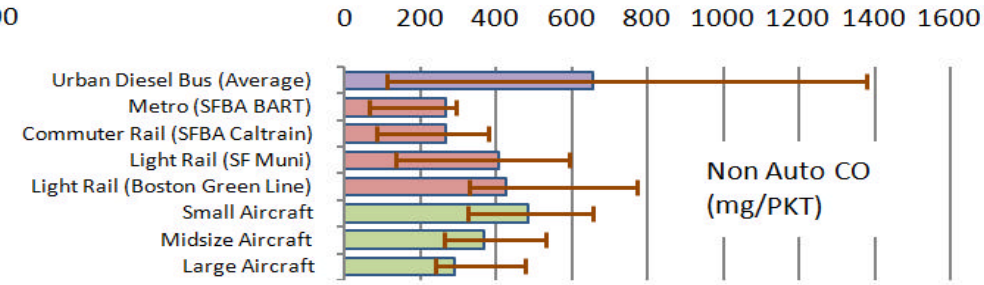












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State of LCA

- Too few LCAs exist
- They are too specific to
  - » a problem
  - » a technology
  - » assumptions
  - » a geographic area
  - » a point in time
- Incomplete
- No policy should be passed without LCA!