Capturing the Environmental Benefits of Nanotechnology

Shannon Lloyd
First Environment

13th Foresight Conference
October 22-27, 2005
San Francisco, CA

FIRST ENVIRONMENT

Potential Environmental Benefits

Improved ability to detect and eliminate pollution	→	Improved air, water, and soil quality
Improved pollution control technology	→	Improved air, water, and soil quality
High precision manufacturing	→	Reduced waste
Design and control chemistry	→	Reduced reliance on toxic and scare materials
Energy efficient production and storage	→	Lower energy requirements
Improved photovoltaics	→	Less reliance on fossil fuels

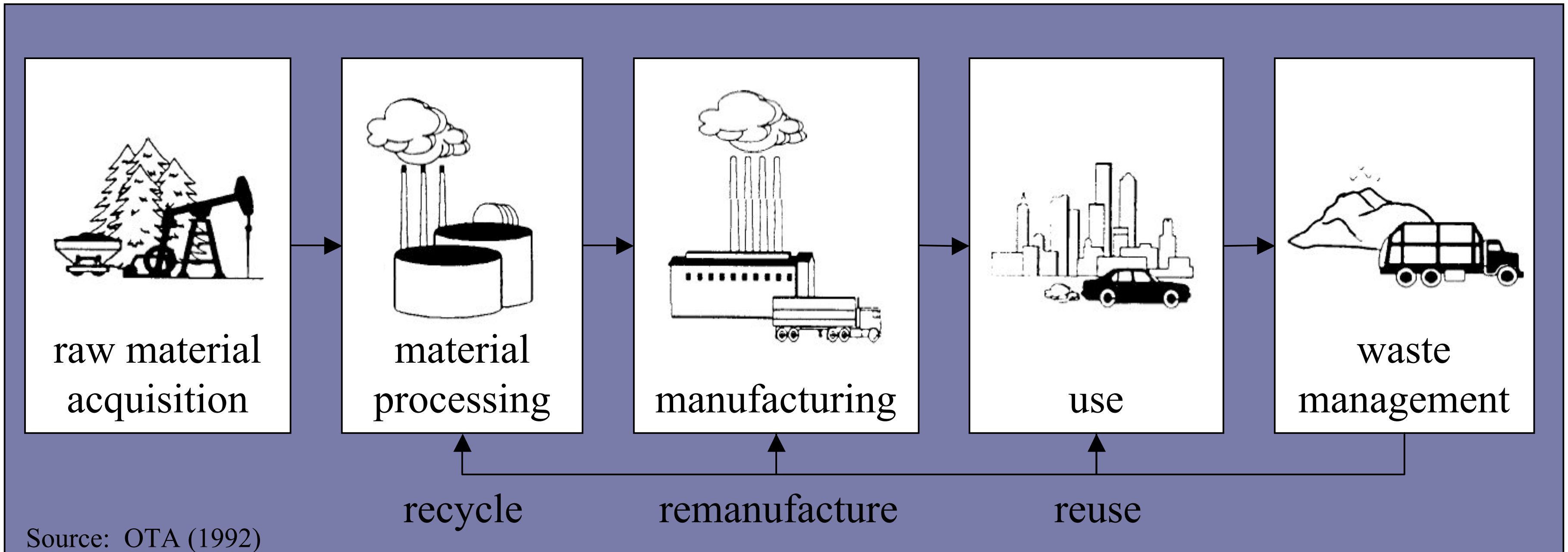
Potential Environmental Harm

Development and release of toxic engineered nanoparticles	→	Reduced human and ecosystem health
Top-down methods with high waste-to-product ratios	→	Increase in materials required and waste during manufacturing
High energy requirements for synthesizing nanoparticles	→	Increased in energy usage
Self-assembly reactions using toxic substances	→	Increase in toxic releases
Complex issues with material recovery	→	Lower recovery and recycling rates

From an Environmental Perspective …

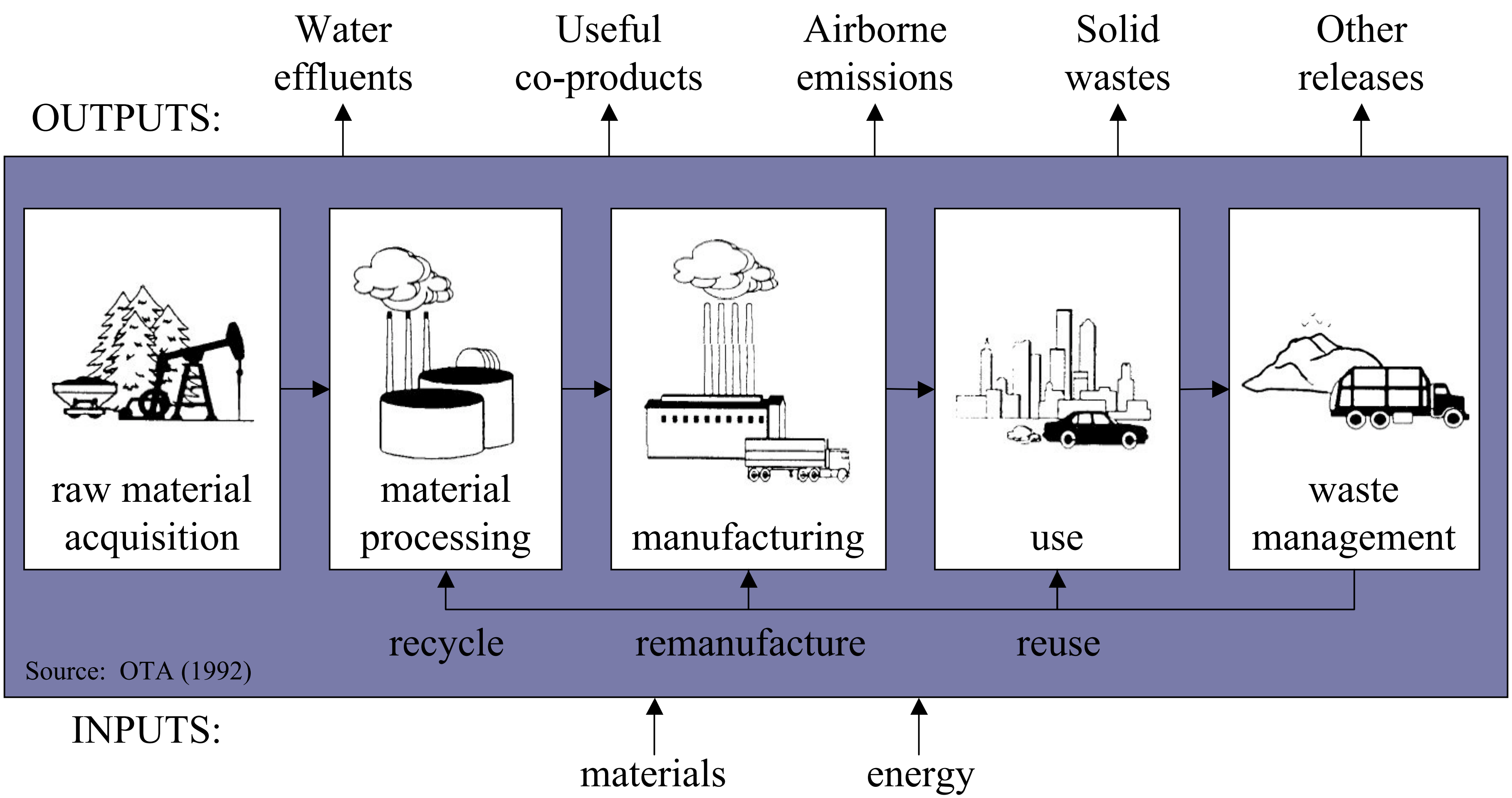
What is the net impact?

Product Life Cycle



Source: OTA (1992)

Life Cycle Assessment



Life Cycle Impact

Impact categories in US EPAs TRACI

Ozone Depletion	Photochemical Smog	Ecotoxicity
Global Warming	Human Health - Cancer	Fossil Fuel Use
Acidification	Human Health - Noncancer	Land Use
Eutrophication	Human Health - Criteria	Water Use

Using LCA to Measure the Net Impact

- **National Science and Technology Council**, Committee on Technology, Subcomittee on Nanoscale Science, Engineering and Technology, "Nanotechnology Grand Challenge in the Environment: Research Planning Workshop Report," 2004.

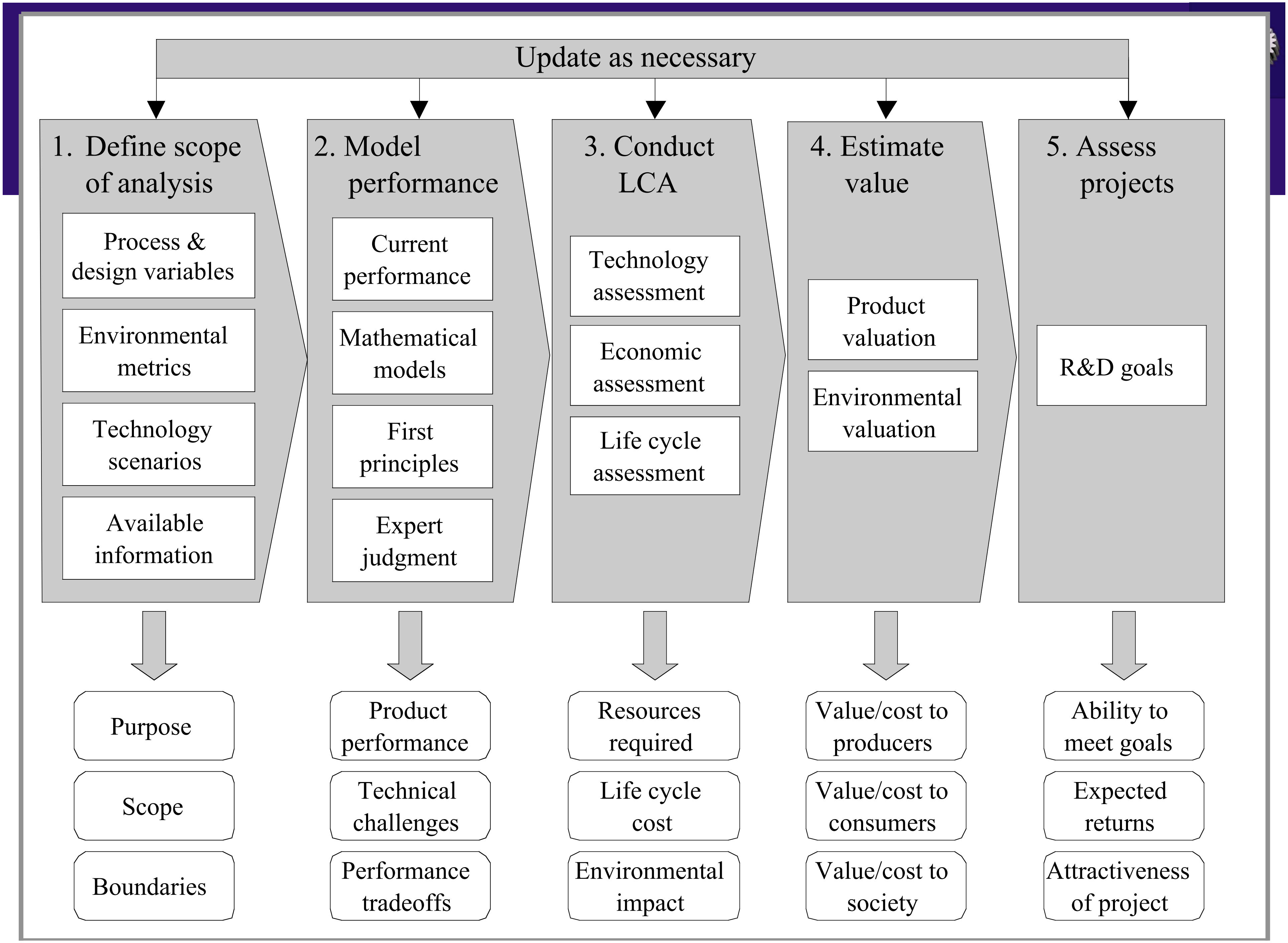
- **Commission of the European Communities**, "Communication from the Commission: Towards a European strategy for nanotechnology," COM(2004) 338 final, December 5, 2004. 21.

- **The Royal Society and The Royal Academy of Engineering**. "Nanoscience and nanotechnologies: opportunities and uncertainties," July 29, 2004.

Using LCA to Measure the Net Impact

"We recommend that a series of lifecycle assessments be undertaken for the applications and product groups arising from existing and expected developments in nanotechnologies, to ensure that that savings in resource consumption during the use of the product are not offset by increased consumption during manufacture and disposal."

The Royal Society and The Royal Academy of Engineering "Nanoscience and nanotechnologies: opportunities and uncertainties," July 29, 2004.

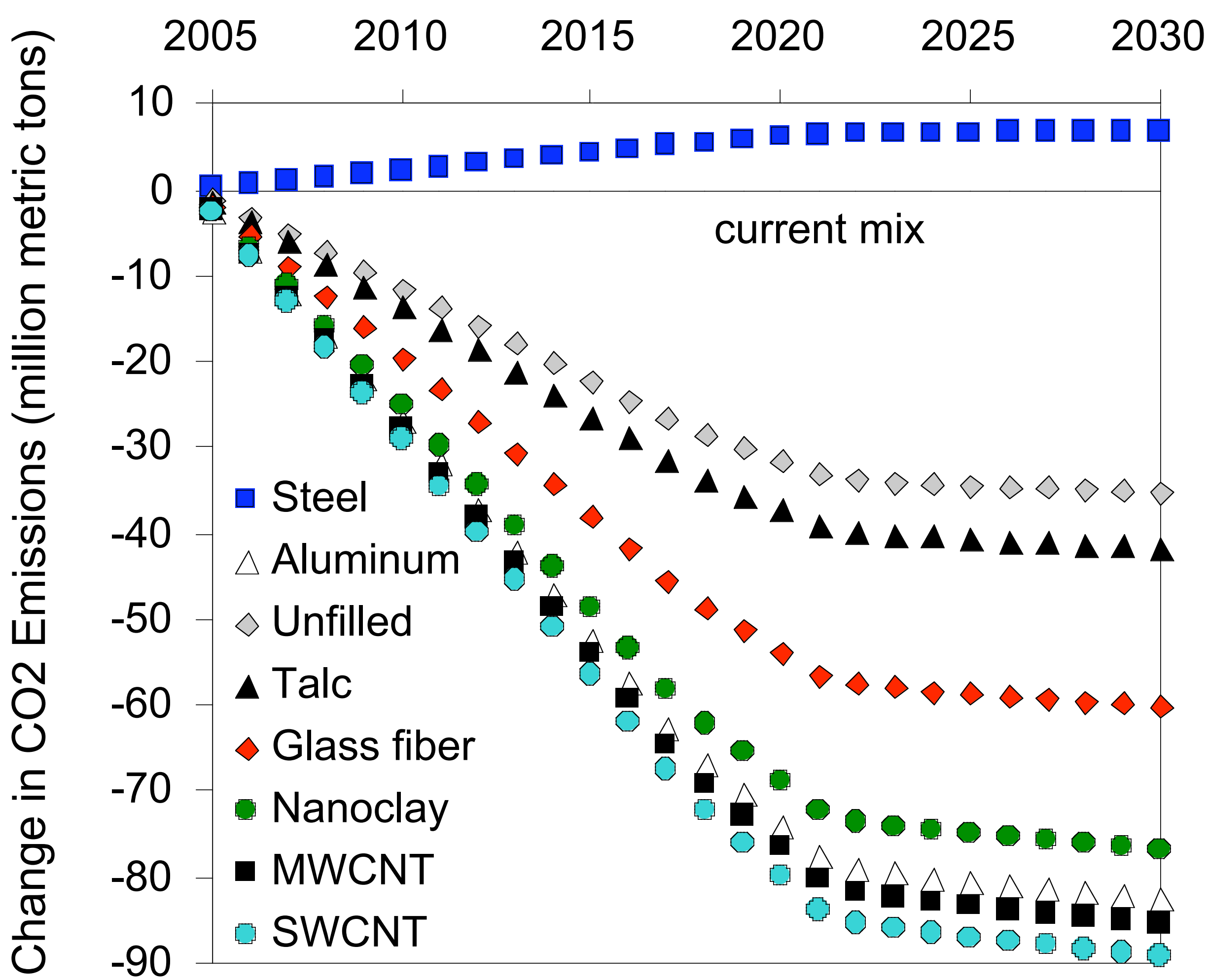

Update as necessary
1. Define scope of analysis
Process & design variables
Environmental metrics
Technology scenarios
Available information
2. Model performance
Current performance
Mathematical models
First principles
Expert judgment
3. Conduct LCA
Technology assessment
Economic assessment
Life cycle assessment
4. Estimate value
Product valuation
Environmental valuation
5. Assess projects
R&D goals
Purpose
Scope
Boundaries
Product performance
Technical challenges
Performance tradeoffs
Resources required
Life cycle cost
Environmental impact
Value/cost to producers
Value/cost to consumers
Value/cost to society
Ability to meet goals
Expected returns
Attractiveness of project

LCA Studies Conducted

- Using nanocomposite body panels in automobiles
  - Lloyd and Lave, Environmental Science & Technology, 2003.
  - Lloyd, PhD Thesis, 2004.

- Using nanofabrication to position and stabilize nanoscale PGM particles in automotive catalysts
  - Lloyd, Lave, and Matthews, Environmental Science & Technology, 2005
  - Lloyd, PhD Thesis, 2004.

Sample Results (1) - Use



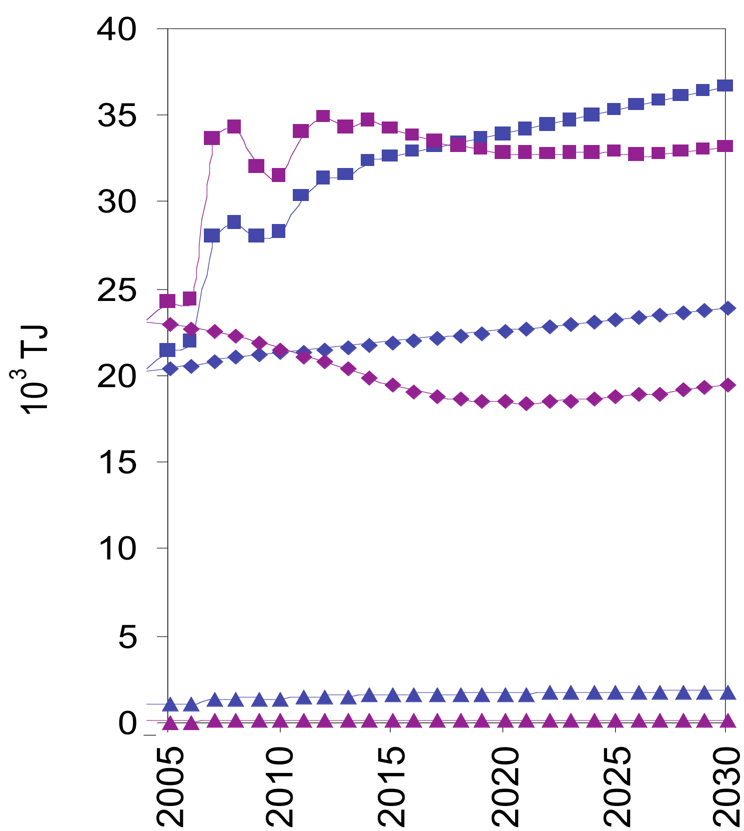
Current mix

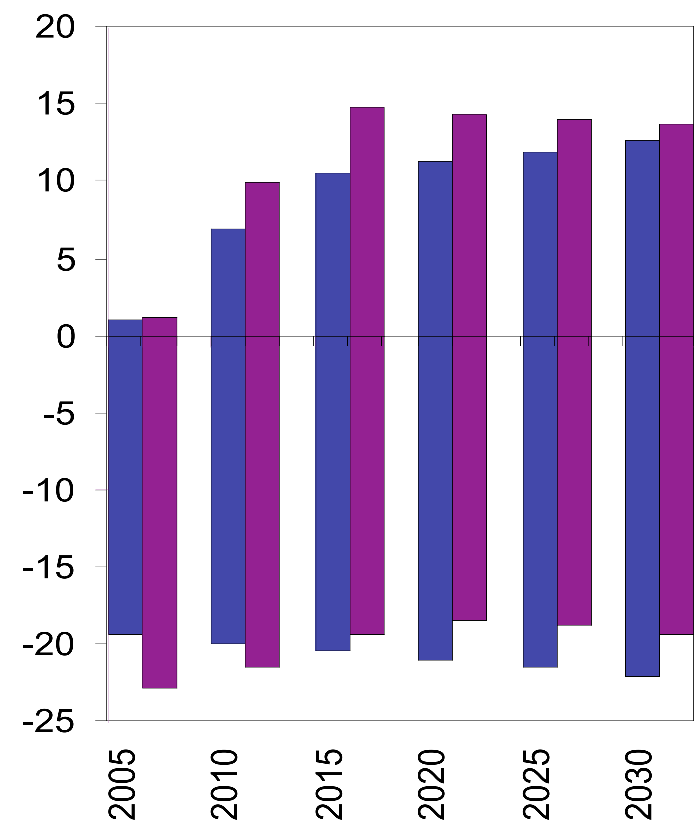
- 91% steel
- 6% aluminum
- 3% composites

Fleet characteristics

- Projected sales
- Vehicle life
- Annual miles
- Survivability rates

Sample Results 2 – Raw Matls





EIO-LCA Baseline
EIO-LCA Current technology
EIO-LCA Fully effective nanotechnology
GaBi Baseline
GaBi Current technology
GaBi Fully effective nanotechnology

Other Nanotechnology LCAs

Steinfeldt et al., IOEW, 2004.

Application	Conventional	Nanotechnology
Aluminum coating	Water, solvent and powder varnish	Sol-gel nano-varnish
Styrol synthesis	Iron-oxide catalytic converter	Nanotube-based catalytic converter
Displays	CRT, LCD, and plasma	OLED and CNT-FED
Lighting	Conventional and energy saving light bulbs	LEDs

Nanomag (EU programme)

nano-coatings vs. chromium-based coatings for magnesium alloys

Studies Conducted To Date

- Only a few life cycle studies have been conducted
- Limited emphasis on total (direct and indirect) environmental implications of foreseeable nanotechnology scenarios.
- Detailed analysis of use or material acquisition
- Limited processing, fabrication, and end-of-life analyses
- Qualitative discussion about engineered nanoparticle releases

Summary of Findings

- High potential environmental savings from reducing use-phase energy consumption or in-product material (but not in all cases)
- Use of nanotechnology does not necessarily result in environmental savings
- Environmental implications of other life cycle stages is not clear

Next Steps

Public

- Quantify environmental impact of producing nanostructures
- Incorporate new findings about nanoparticles (fate, transport, toxicity) into LCA impact models
- Establish methods for managing nanoparticle release data (e.g., mass may not be the appropriate metric for quantifying nanoparticle releases in LCA)

Private

- Incorporate LCA into nanotechnology R&D

For More Information

Shannon Lloyd

(202) 289-1126

sml@firstenvironment.com