Measurement Needs in Sustainability and Materials Performance

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Materials Sustainability

- **This presentation focuses on materials and generic measurement needs related to materials and sustainability analysis.**

- **Water and Energy are important issues in sustainability that are not addressed here to allow for this focus on materials.**

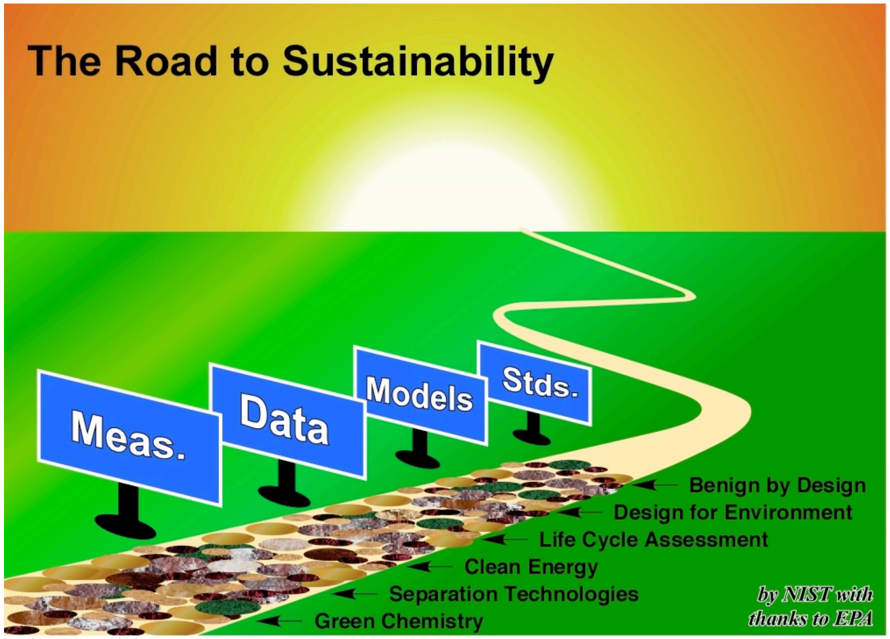
- **Performance means the properties that govern how well a material meets its intended function over its service life and reliability.**

- **Hypothesis:**
  To be successful, sustainability is going to require improved measurements, data, models, and standards that reduce uncertainties in the prediction of materials properties, performance, and lifetimes.

"We need both the commitment to sustainability and the accomplishments of science"
C.O. Holliday, Jr., Chairman & CEO, DuPont, October 28, 2007 (2).

Sustainability is

- **Meeting the needs of the present without compromising the ability of future generations to meet their needs (3).**
- **A long-term remedy to the demand society places on the environment and the limited resources of the planet Earth,**
- **A potentially disruptive challenge to industry that cannot be solved without advances in:**
  - **scientific understanding and technology**
  - **advances in measurement methods and standards**
  - **data and tools that use materials property data**

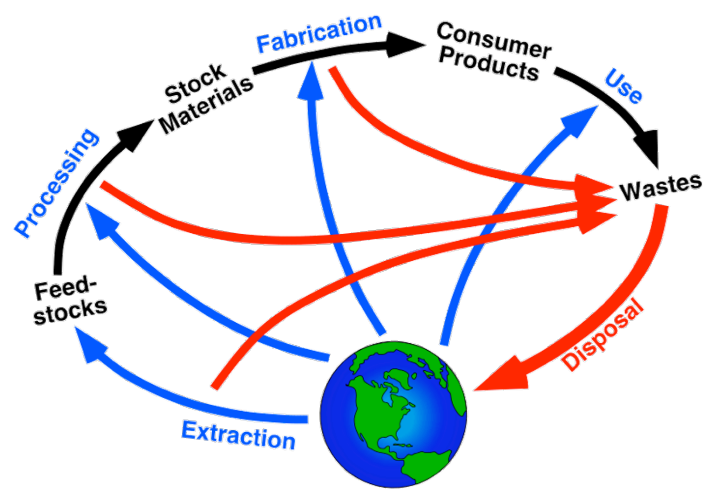


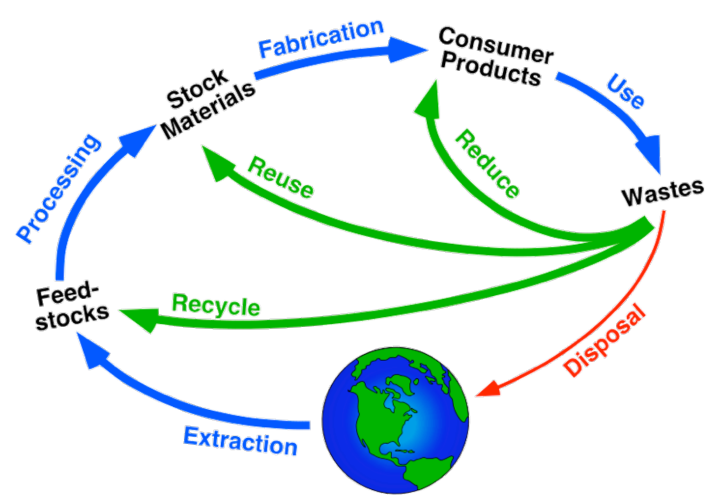
Environmental Stewardship and Sustainability?

- Sustainability is an approach to environmental stewardship

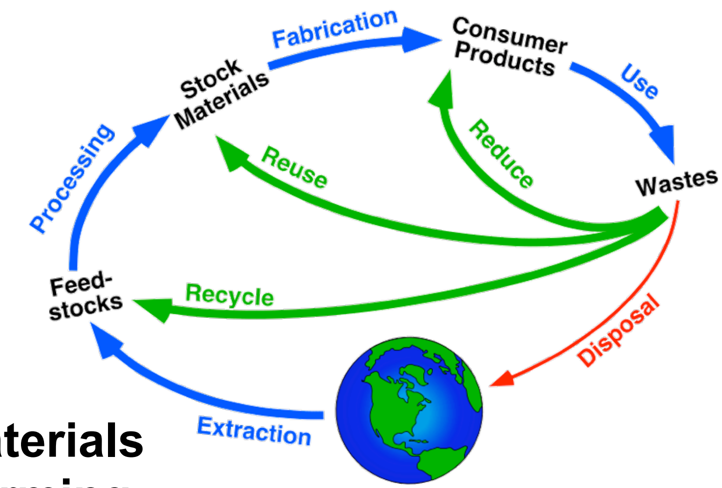
- Other approaches to environmental stewardship
  - Laissez faire
  - ID and regulation
  - Ultra green

- Two distinguishing features:
  - The triple bottom line
    - Societal factors (People)
    - Environmental factors (Planet)
    - Marketing factors (Profit)
  - Full Life Cycle Assessment (LCA)
    - Scientifically sound
    - Impacts from all sources considered
    - Performance and lifetime





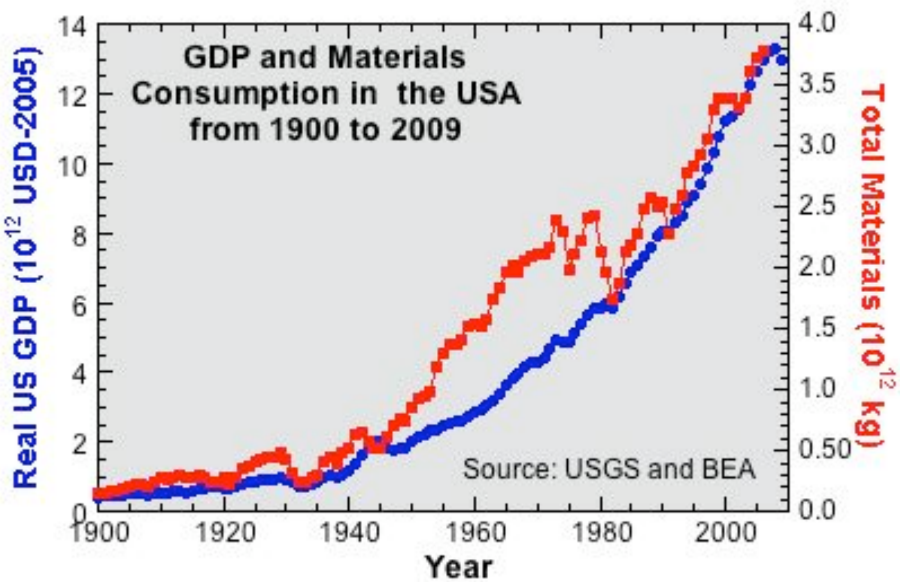
The Goal of Sustainability is to Make Everyone Happy

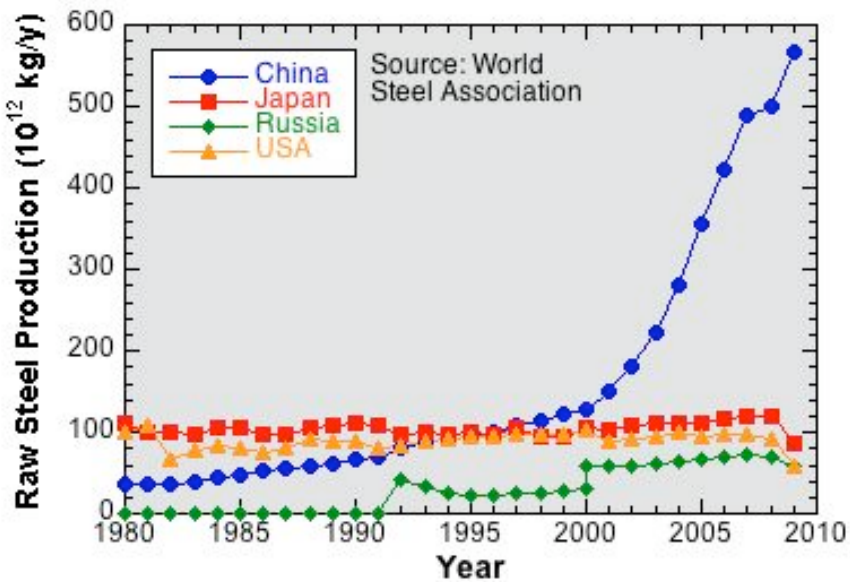


- People
  - Jobs and education
  - Public and employee safety
  - Standard of living
- Planet
  - Reduced consumption of raw materials
  - Reduced pollution and global warming
  - Continued health and diversity of species
- Profit
  - Stockholder support
  - Continued growth and employment
  - Continued improvement in environmental practices

Materials Sustainability is a National and International Priority

- With less than < 5% of the population, the US accounts for about 25% of the World's GDP, 21 % of the energy consumed and 20 % of the CO_2 released (4-8).
- The US consumes about 1/3 of the materials produced worldwide (6).
- Historically, materials consumption and GDP grow at about the same rate (below left) (5,6).
- If everyone consumed at the US rate, it would take 4-5 Earths to meet our needs (9).
- Continued growth and economic security while developing nations grow will require an uninterrupted supply of materials or suitable replacements (below right) (10)
- The continued competitiveness of industries will depend on their ability to adjust to sustainability and regulation driven changes in materials



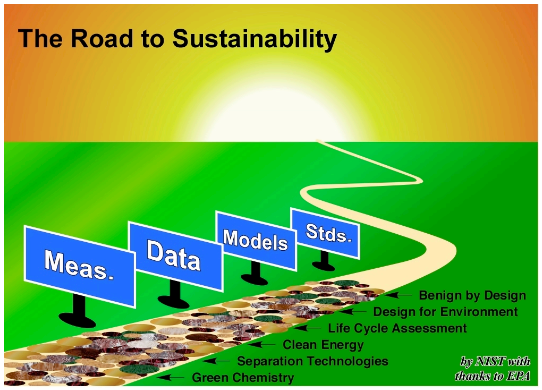


Three Technical Challenges in Materials Sustainability

1. Cleaner-Greener Manufacturing - New technologies for processing and manufacturing that reduce environmental impacts.

2. Competitive Sustainable Materials – New materials that maintain or improve marketplace competitiveness of products while reducing environmental impacts.

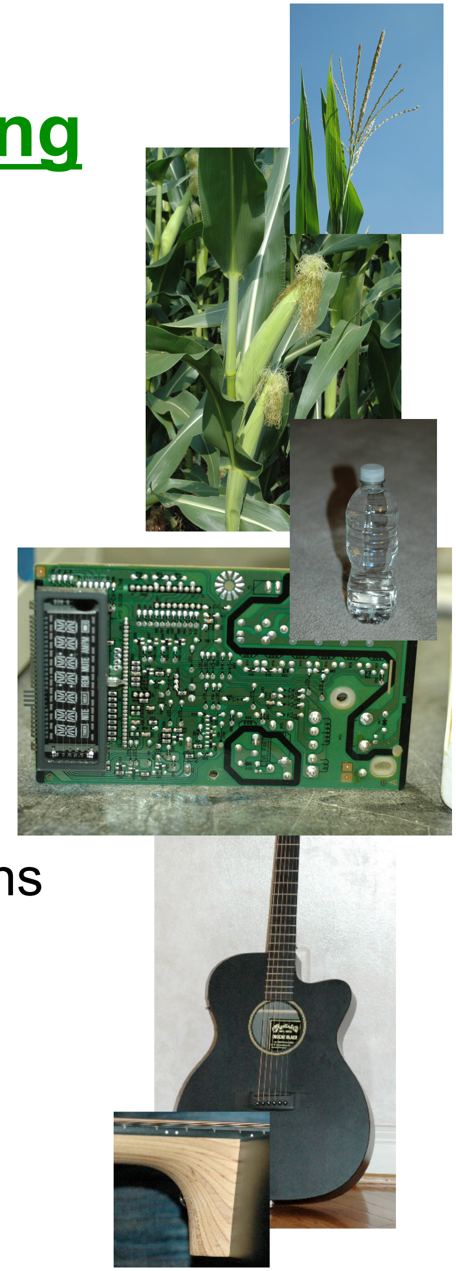
3. Reduce, Reuse, and Recycle – Materials and methods that enable industry to reduce wastes, reuse materials, and recycle more efficiently.



Technology Challenge #1

Cleaner-Greener Manufacturing

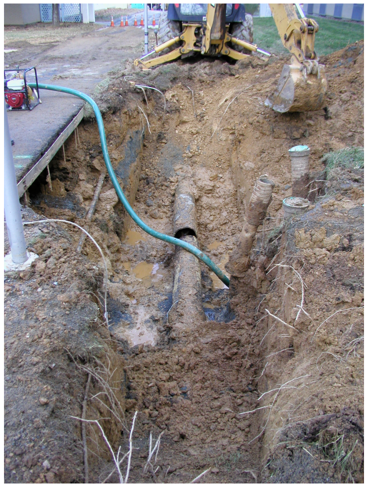
- Challenges:
  – Reduce consumption of raw materials and energy
  – Replace raw materials with renewable and recycled materials
  – Reduce wastes generated
  – Reduce the use of toxic materials in products and processes
- Measurement Needs:
  – Process measurement methods and controls
  – Measurement methods and standards for toxicity
  – Critical data on the effects of processing modifications on properties of materials
- Authentication:
  – R. Rapp, Materials Today (12/04) 13.
  – Nature, 419 (6907) 543 (2002).
  – Chem. & Eng. News, 79 (2001) 27-34.



Technology Challenge #2

Competitive Sustainable Materials

- Challenges:
  - Staying competitive while moving to sustainable materials and processes
  - Finding sustainable materials that meet or exceed the performance of existing materials
  - Avoiding failures due to "sustainable" changes in materials or processes
- Measurement Needs:
  - A new generation of reliable test and performance prediction methods and standards
  - Performance based standards for renewable and recycled materials purity and properties
  - Critical data on the performance of sustainable materials
- Authentication:
  - Plastics Engineering (6/07) 44
  - "Sustainability in the Chemical Industry" National Academy Press (2005)

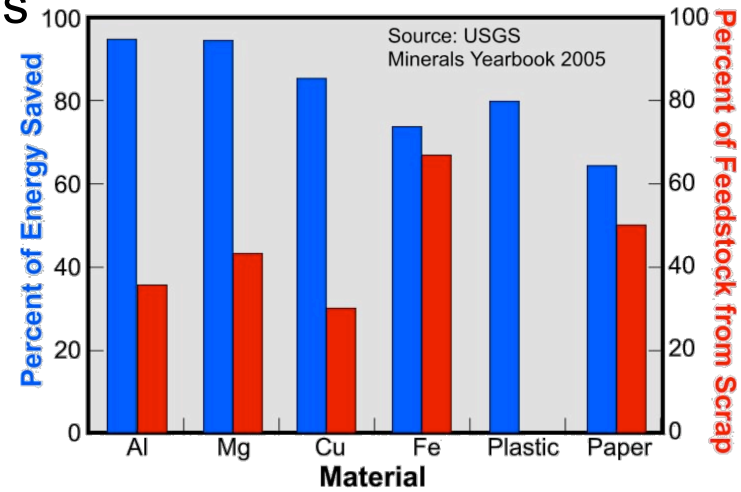


Technology Challenge #3

Reduce, Reuse, and Recycle

- Challenges:
  - Reducing waste with durable and reusable materials
  - Better sorting of wastes
  - Producing high quality feedstocks for materials production (recycling not downcycling)
  - Performance of materials with recycled content
  - True recycling not "down-cycling"

- Measurement Needs:
  - Rapid measurement and identification methods for waste sorting
  - Certification of feedstock quality and standards
  - Materials durability measurement methods
- Authentication:
  - Senate Bill 1587 IS, 110th Congress, June 2007
  - D.B. Spencer, JOM 163 (4) (2005) 46-51
  - L. Zhang, T. Dupont, Mater. Sci. Forum 546-549 (2007) 25-36



Sustainability?

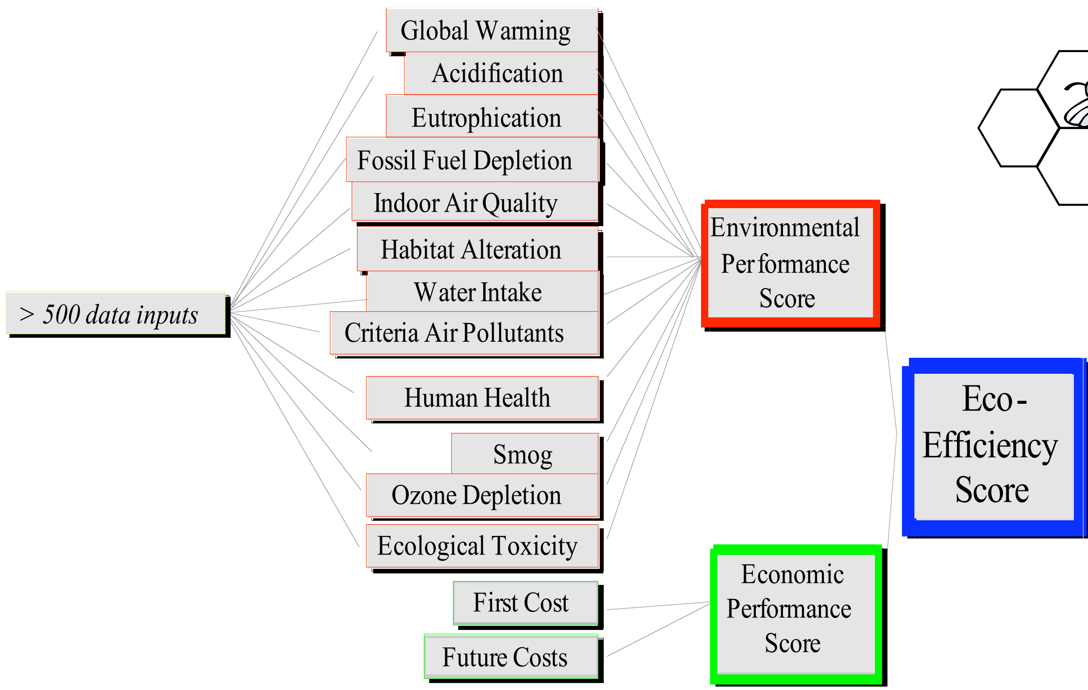
- The measurement needs presented are appropriate for any proactive form of environmental stewardship
- Sustainability is not just any form of environmental stewardship. It is a specific approach that relies on the triple bottom line and full life cycle assessment (LCA) of impacts.
- What is specifically required for sustainability to be successful
- Triple bottom line measurement needs
  – Impacts that are difficult to quantify
  – Comparison of disparate measures
  – Requires non-scientifically evaluated weighting factors
- Scientifically sound full life cycle assessments (LCAs)
  – Requires data on every material, process, and step
  – Requires appropriate measurements
  – Requires scientifically sound analysis routines

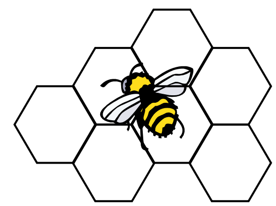
An Example of a Sustainability Decision Making Tool

BEES - Building for Environmental and Economic Sustainability

A Life-Cycle Approach Based on Consensus Standards developed by the NIST Building and Fire Research Laboratory over the last 15 years

- **ISO 14040: Environmental Life-Cycle Assessment**
- ➢ **Provides general framework for assessing environmental impact**
- ➢ **Follows process flow from initial resource extraction to disposal**





If a company thinks that they are making something the best way possible, how can measurements and data convince them that making changes will not have a negative impact product performance and sales?

However, these analyses are only as good as the underlying data and assumptions

Basic Approach to LCA Analysis

- **Waste generation rate**

$$\left(\frac{dW}{dt}\right)_U = \frac{\left(e_1 + e_2 + e_3 + \ldots + e_i\right)_U}{\langle t_{LC} \rangle} = \frac{\sum_i \left(e_i\right)_U}{\langle t_{LC} \rangle}$$

- **Expected service life of product or materials**

$$\langle t_{LC} \rangle = k \langle t_f \rangle$$

- **Where k is the materials performance (i.e. strength) correction factor and t_f is the expected service life of the material.**

- **A large positive change in an e_i that produces a small negative change in either k or t_f can actually increase the waste generation rate.**

- **Therefore, it is critical to understand the impact of sustainability driven changes in materials and processes on microstructure, properties, and performance.**

Conclusions

- Sustainability promises to make everyone happy
- Generic measurement needs were indentified in three areas:
  - Cleaner-Greener Manufacturing,
  - Competitive Sustainable Materials, and
  - Reduce, Reuse, and Recycle.
- Sustainability will make everyone happy only if LCA works.
- A large amount of measurements, data, computer analysis tools, and standards will be required for LCA to work and accurately guide decision making.
- The most critical terms in LCA waste generation rate analysis will be those representing materials performance and service lives. Therefore, success will be critically dependent on the measurements and assumptions used for these terms.
- LCA analyses will create a need for improved data in all areas of materials technology, but the greatest need will be in those areas with the greatest impact on the reliability of the LCA predictions.

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