Breakout Session #1: Nanotechnology Economic Benefits for the Environment

Federal Interagency Workshop on Nanotechnology & the Environment: Applications & Implications

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Relative Magnitude of US Nanotechnology Market Compared to US Environmental Market

US Nanotechnology Market

- $0.4 billion/year US nanotechnology business activities (2002)
- $0.7 billion/year US gov't R&D funding for nanotechnology (2003)

US Environmental Market

- First survey of private sector commercial environmental products, services & construction measured $103 billion/year market in 1995 (774,000 employees; 34,000 companies):
  - $35.9 billion/year solid waste
  - $31.1 billion/year water treatment
  - $15.7 billion/year misc
  - $6.3 billion/year admin/mgt/engineer
  - $6.0 billion/year air treatment
  - $5.4 billion/year monitoring/analysis
  - $2.4 billion/year energy conservation
  - $0.2 billion/year noise pollution control
- Inclusion of public sector, legal & internal business activities yields $200 billion/year total US environmental economic activities (2002).
- $17.7 billion/year in industrial pollution abatement control expenditures (capital + O&M; 1999 Census PACE)
  - $8.5 billion/yr air pollution
  - $6.4 billion/yr water pollution
  - $2.4 billion/yr solid+haz waste
  - $0.4 billion/yr multimedia
- $2.2 billion/year residential water treatment revenues (1998).

Relative magnitudes: $1.1 billion/year to $200 billion/year = 0.6%

Workshop Breakout Group Activities

- Group Task 1: Define possible environmental benefit categories/metrics.
- Group Task 2: Identify candidate examples of potential environmentally-beneficial nanotechnologies.
- Group Task 3: Evaluate each candidate nanotechnology against environmental benefit categories from Task 1.

Group Task 1: Six Metrics of Potential Environmental Benefits From Nanotechnology

- Economic locus: Which economic sector, industry, and/or economic activity is involved (i.e. where is the beneficial nanotechnology application nested and manifest in the US economy)?

- Mechanism of benefits: How does the nanotechnology physically generate environmental benefits?
  - Via its design intention for direct application to environmental areas such as waste treatment, contaminated site remediation, environmental monitoring; or
  - Via secondary/indirect environmental impact resulting from another design intention application (e.g. manufacturing or consumer product innovation resulting in collateral environmental benefit).

- Environmental media affected: Will benefits accrue to air, land, water, and/or ecosystems (e.g. reduction in toxic chemical loadings, reduction in human or ecological exposures)?

- Occurrence of benefits: One-time (e.g. single year), continuous (e.g. annually), intermittent, now, and/or in the future?

- Magnitude of benefits: Physical units affected (e.g. tons, acres, gallons, cubic yards), species/populations affected, monetized value of benefits ($/year).

- Distribution of benefits: are beneficial outputs/ applications localized in impact scope (e.g. site-, species-, or country-specific) or broad (e.g. international, atmospheric, oceanic, biospheric)?

Group Task 2: Candidate Examples of Potential Environmentally-Beneficial Nanotechnologies

- (1) Environmental News Service, 08 Sept 2003 - An ultrafine powder made from iron can be used to clean up contaminated soil and groundwater at thousands of U.S. landfills, abandoned mines and industrial sites, a scientific team funded by the National Science Foundation has found. The so-called nanoscale iron particles - about 1/80,000 of the diameter of a human hair - can be suspended in a slurry and pumped into the core of a contaminated site (also see Wei-xian Zhang, 2003).

- (2) Nanotechnology research is forming part of the quest to prevent and reverse environmental damage. Researchers aim to use nanotechnology to provide efficient and effective filters for water and air, leading to reduced pollution. A membrane that can purify water and is also self-cleaning to avoid contamination should be available in the near to medium-term. Improved catalysts, composed of nanoparticles, are already in use in petrol and chemical processing, resulting in less waste in these processes.

- (3) Perhaps the most promising application in both the environmental and energy areas is the development of fuel cells, with many different uses. Research is being undertaken into the effectiveness of carbon nanotubes at storing hydrogen; these have the potential to power cars, amongst other things, with water as the only emission, although this is some way from commercialisation.

- (4) Photovoltaics are another focus of nanotechnology development, with the ultimate aim being highly efficient, cheap, lightweight, possibly flexible, solar cells made from plastics. A breakthrough in this field is predicted to occur by 2020. Biomimicry is one key element in this research, as scientists attempt to copy plants' photosynthesis mechanism. The conversion of sunlight to hydrogen would bring together photovoltaics and biomimicry, and should be possible in the medium-term. Taken together, improvements in sources of renewable energy, with the development of storage of gaseous hydrogen and the improvement of fuel cells, could lead to a viable 'hydrogen economy' in which the energy needs of society were no longer reliant on fossil fuels.

- (5) Nanomag looks to find durable and clean nanocomposite coatings for cars, allowing the phaseout of chromate-based conversion coatings.

Examples 2, 3, 4 above from Aug 2003 ESRC report, p.22; http://www.esrc.ac.uk/ESRCContent/DownloadDocs/Nanotechnology.pdf

Group Task 2: Candidate Examples of Potential Environmentally-Beneficial Nanotechnologies (cont'd)

- (6) Microchem is pushing for a breakthrough on 'laboratory-on-a-chip' nanosensors for water monitoring; chemical analyses are typically 100 times faster, enabling rapid identification of chemicals at nanoliter scale in wastewater.

- (7) Self-assembled monolayers, i.e. substances spontaneously forming a one-molecule thick layer on a surface, are a technology showing promise for environmental sanitation. A layer of functional groups tailored to bind to heavy metals and assembled on mesoporous surfaces has been shown to separate and remove mercury from aqueous and organic liquids and gaseous streams (Bastani & Fernandez, 2002).

- (8) We estimate potential selected economic and environmental impacts associated with the use of nanotechnology in the automotive industry. In particular, we project the material processing and fuel economy benefits associated with using a clay-polypropylene nanocomposite instead of steel or aluminum in light-duty vehicle body panels. Although the manufacturing cost is currently higher, a life cycle analysis shows potential benefits in reducing energy use and environment discharges by using a nanocomposite design (Lloyd & Lave, 2003).

- (9) Sustainability: Nanotechnology will improve agricultural yields for an increased population, provide more economical water filtration and desalination, and enable renewable energy sources; it will reduce the need for scarce material resources and diminish pollution for a cleaner environment. For example, in 10-15 years, projections indicate that such nanotechnology-based lighting advances have the potential to reduce worldwide consumption of energy by more than 10%, reflecting a savings of $100 billion per year and a corresponding reduction of 200 million tons of carbon emissions (M. Roco, 2001).

- (10) For an overview of how "[n]anotechnology could substantially enhance environmental quality and sustainability through pollution prevention, treatment, and remediation", see Masciangioli & Zhang, 01 March 2003; http://www.nano.gov/GC_ENV_PaperZhang_03-0304.pdf

Examples 5 & 6 from Nov 2002 "Smart Materials Bulletin".

Group Task 3: Matrix for Evaluating Candidate Nanotechnologies According to Benefit Metrics

Type of nano-technology	Economic locus	Mech-anism	Media affected	Occur-rence	Magnitude	Distribution
1.						
2.						
3.						
4.						
5.						
6.						
7.						
8.						
9.						
10.						

EPA Advertisement: Nanotechnology Environmental Benefits Research Funding Opportunity

- Application Deadline: 11 Dec 2003
- Research Sponsor: EPA Office of Research & Development, National Center for Environmental Research, FY2003 Science to Achieve Results (STAR) Program.
- Research Topic: Impacts of Manufactured Nanomaterials on Human Health & the Environment.
- Research Grants: 12 grants @$115,000/year for up to 3 years.
- Application Website: http://es.epa.gov/ncer/rfa/current/2003_nano.html
- Proceedings of EPA's Progress Review Workshop on the FY2001 Nanotechnology & the Environment Grant Program (featuring 19 specific examples of nanotechnology environmental benefits): http://www.nano.gov/GC_ENV_EPA2002_Proc_03-0204.pdf