Sustainable Nanotechnology Organization

Research | Education | Responsibility

Sustainable Nanotechnology: Where did it come from, What is it, and Why an organization?

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Sustainable Nano Organization
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SNO Conference, Nov. 10, 2016

Outline

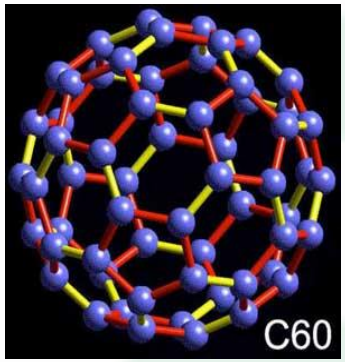
A. History of the development of sustainable nanotechnology, a US perspective.

B. Discussion of sustainability

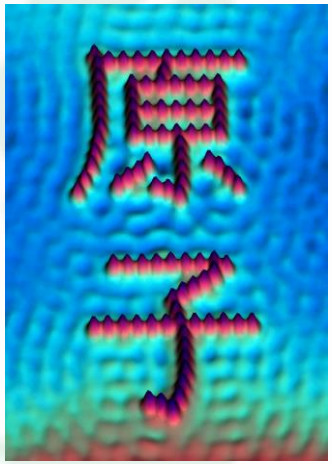
C. A case for a professional society

Brief, Pre-Federal History

Richard Feynman



Eric Drexler



Kanji for "atom"

1959- "There's Plenty of Room at the Bottom" Feynman

1965 – Conductors and Semi-Conductors Moore's Law

1974 – N. Taneguchi : Nano-technology

1986 – Nobel Prize: Ernst Ruska, Gerd Binning, Heinrich Rohrer (electron microscope)

1986 – Eric Drexler "Engines of Creation: The Coming Era of Nanotechnology"

1989 – IBM-Don Eigler and Erhard Schweizer

1991—Sumio Iijima Carbon nanotubes

1996 -- Nobel Prize Harold Kroto, Robert Curl, Richard Smalley

1990 - Submicron Particle Workshop: NSF

1996-M. Roco + colleagues

1997-1998 – "Partnership in Nanotechnology"

1998 - Interagency Working Group on Nanoscale Science, Engineering and Technology (IWGN)

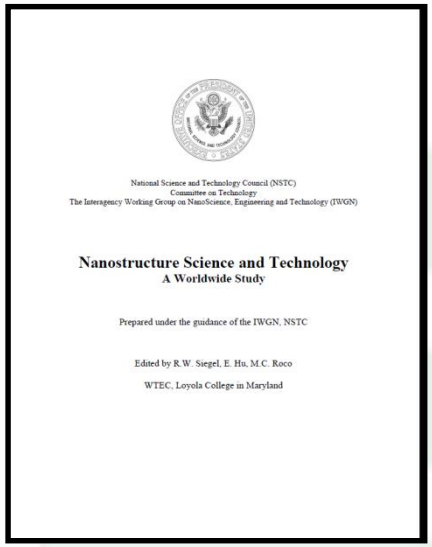
1999-Clinton's Challenge and Legacy

Mikhail (Mike) Roco

Documents

Interagency Working Group on Nanoscience, Engineering and Technology (IWGN)- NSTC CoT

"The emerging fields of nanoscience and nanoengineering are leading to unprecedented understanding and control over the fundamental building blocks of all physical things. This is likely to change the way almost everything—from vaccines to computers to automobile tires to objects not yet imagined—is designed and made." 1999


National Science and Technology Council (NSTC)
Committee on Technology
The Interagency Working Group on NanoScience, Engineering and Technology (IWGN)

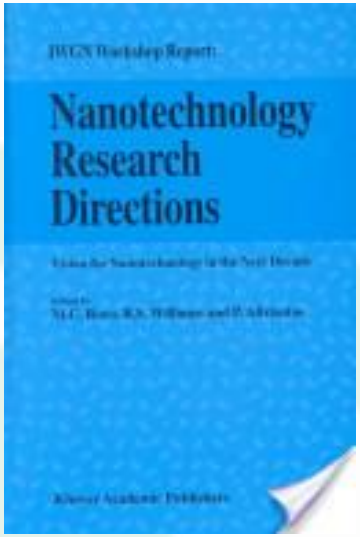
Nanostructure Science and Technology
A Worldwide Study

Prepared under the guidance of the IWGN, NSTC

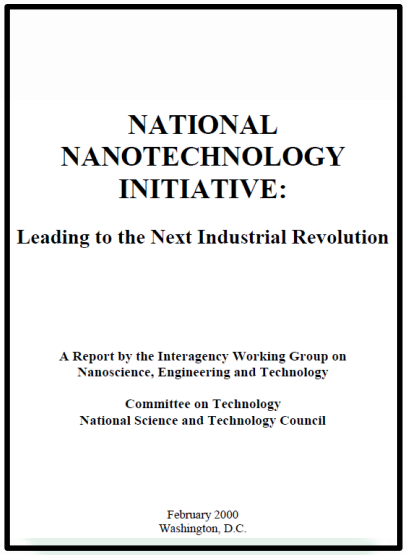
Edited by R.W. Siegel, E. Hu, M.C. Roco

WTEC, Loyola College in Maryland

NSTC/IWGN Report: International Study (Sept. 1999)



Original Full IWGN Report (Sept. 1999)


NATIONAL
NANOTECHNOLOGY
INITIATIVE:

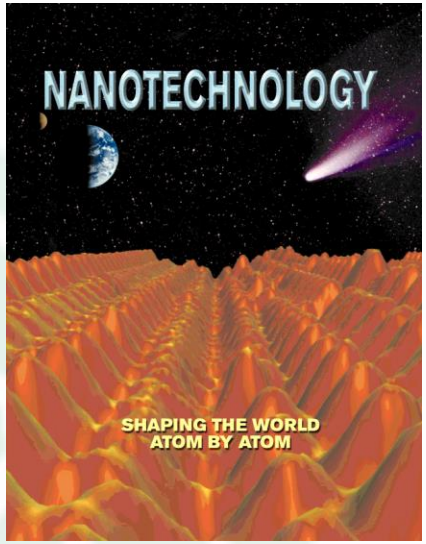
Leading to the Next Industrial Revolution

A Report by the Interagency Working Group on
Nanoscience, Engineering and Technology

Committee on Technology
National Science and Technology Council

February 2000
Washington, D.C.

IWGN Report Prepared For Congress (Feb. 2000)



1999-Public Brochure

The ‘90s and the Beginning

President Bill Clinton’s Legacy: The National Nanotechnology Initiative (NNI)

Bill Clinton, President

Tom Kalil, National Economics Council

Neil Lane, NSF, OSTP, National Science Advisor

National Nanotechnology Initiative

DOE NIH OSTP OMB NSF DOD FDA USDA/NIFA USDA/FS EPA NRC USPTO USGS DOL DOEd ITC CPSC DHS DOC BIS DOJ ITIC DOT DOTr DOS NIOSH NASA NIST

Collaborative, Multi-agency, Cross-cut Program Among 25 Federal agencies since 1999

Ensures US Leadership in fundamental R&D to advance understanding and control of matter at nanoscale for:

- **National economic benefit**
- **National security**
- **Improved quality of life**

Barbara Karn

EPA moves into Nanotechnology (1999):

A Nano-environment Research Community is Born

Nora Savage

This research is funded by
U.S. EPA - Science To Achieve Results (STAR) Program
Grant #

EPA Research Framework for
Responsible nanotechnology in the environment

Applications: reactive to existing problems or proactive in preventing future problems.

Implications of interactions of nanomaterials with the environment and possible risks that may be posed by the use of nanotechnology.

2002 NSF funds CBEN

Center Vision:
Transforming Nanotechnology into a Tool to Solve Real-World Problems

CBEN's mission is to discover and develop nanomaterials that enable new medical and environmental technologies.

The mission is accomplished by the following:

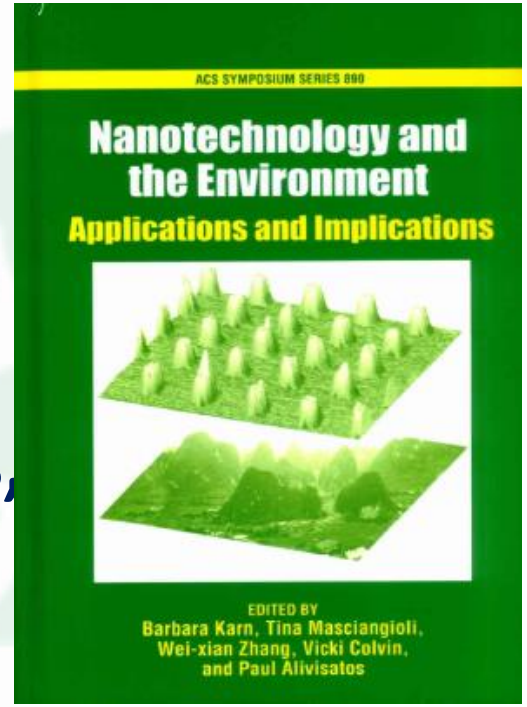
- Fundamental examination of the 'wet/dry' interface between nanomaterials, complex aqueous systems, and ultimately our environment.
- Engineering research that focuses on multifunctional nanoparticles that solve problems in environmental and biological engineering.
- Educational programs that develop teachers, students, and citizens who are well informed and enthusiastic about nanotechnology.
- Innovative knowledge transfer that recognize the importance of communicating nanotechnology research to the media, policymakers, and the general public.

This mission is inspired by the observation that because of their small size and unique properties, nanomaterials interact with and control biological systems in entirely new ways.

2003 becomes a big year for ENV Nano

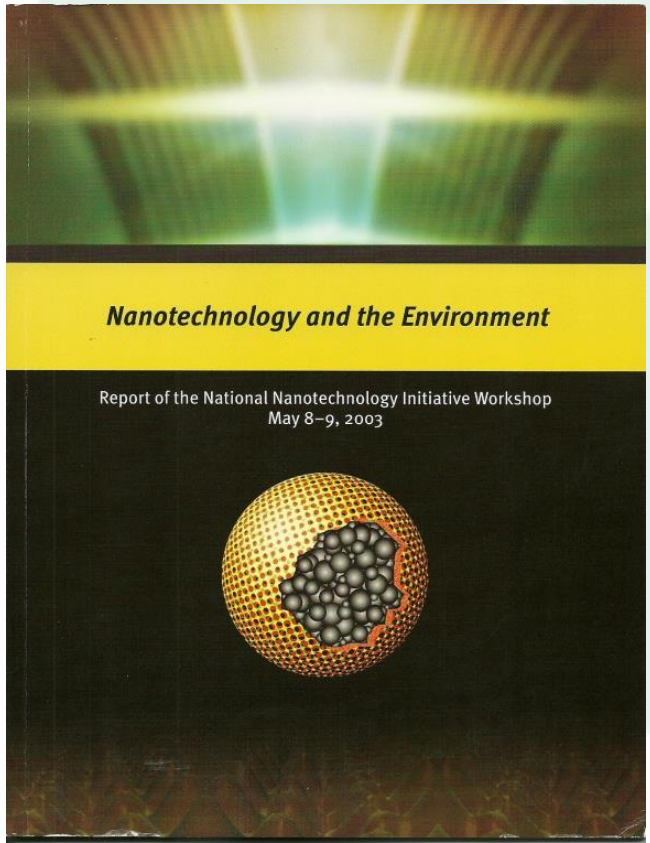
March-- ACS first symposium on Nanotechnology and the Environment

10 sessions, poster session,
over 70 papers,
both applications and implications,
symposium book



2003 becomes a big year for ENV Nano

May-- NNI Workshop on nanotechnology and the Environment



3 sessions on applications:

Applications for :

- **Measurement in the environment**
- **Sustainable materials and resources**
- **Sustainable processes**

2 sessions on Implications:

- **Natural/global processes**
- **Health/environment**

Dec. 3, 2003

108TH CONGRESS
1ST SESSION

S. 189

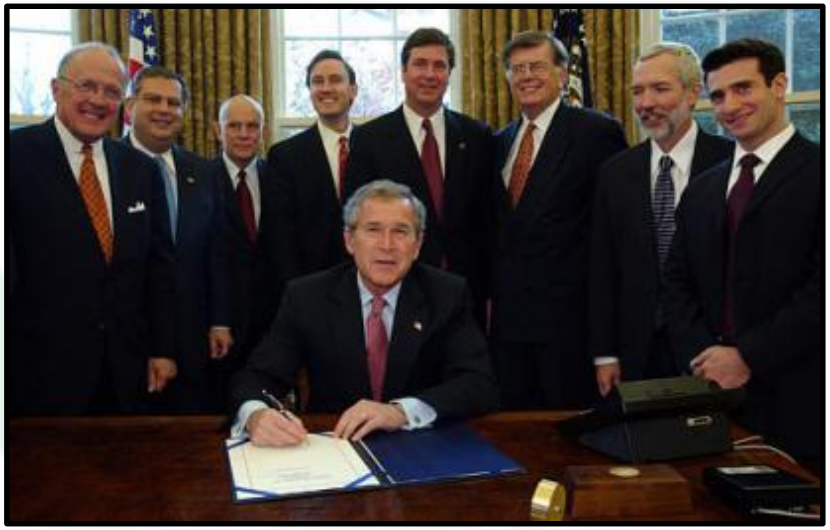
AN ACT

To authorize appropriations for nanoscience, nanoengineering, and nanotechnology research, and for other purposes.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,

SECTION 1. SHORT TITLE.

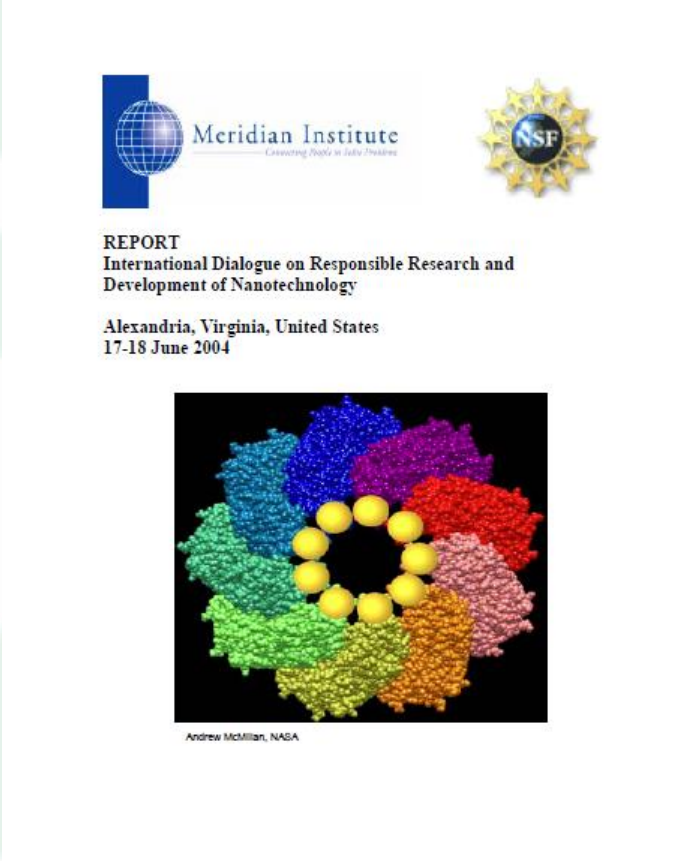
This Act may be cited as the "21st Century Nanotechnology Research and Development Act".



http://www.dfj.com/news/article_98.shtml

…and something else happened at the same time

June, 2004 International Dialogue on Responsible Research and Development of Nanotechnology


Meridian Institute

REPORT
International Dialogue on Responsible Research and Development of Nanotechnology

Alexandria, Virginia, United States
17-18 June 2004

Andrew McMillan, NASA

25 Countries plus the European Union

The four concurrent breakout group discussions focused on:

benefits and risks to the environment;
benefits and risks to human health and safety;
the socio-economic and ethical implications of nanotechnology;
the special consideration of nanotechnology in developing countries

2011 NNI Strategic Plan

Goals

- Advance world-class nanotechnology research and development
- Foster the transfer of new technologies into products for commercial and public benefit
- Develop and sustain educational resources, a skilled workforce, and the supporting infrastructure and tools to advance nanotechnology
- Support responsible development of nanotechnology

2014 NNI Strategic Plan

Goal 4: Support responsible development of nanotechnology

Objective 4.4 Incorporate sustainability in the responsible development of nanotechnology

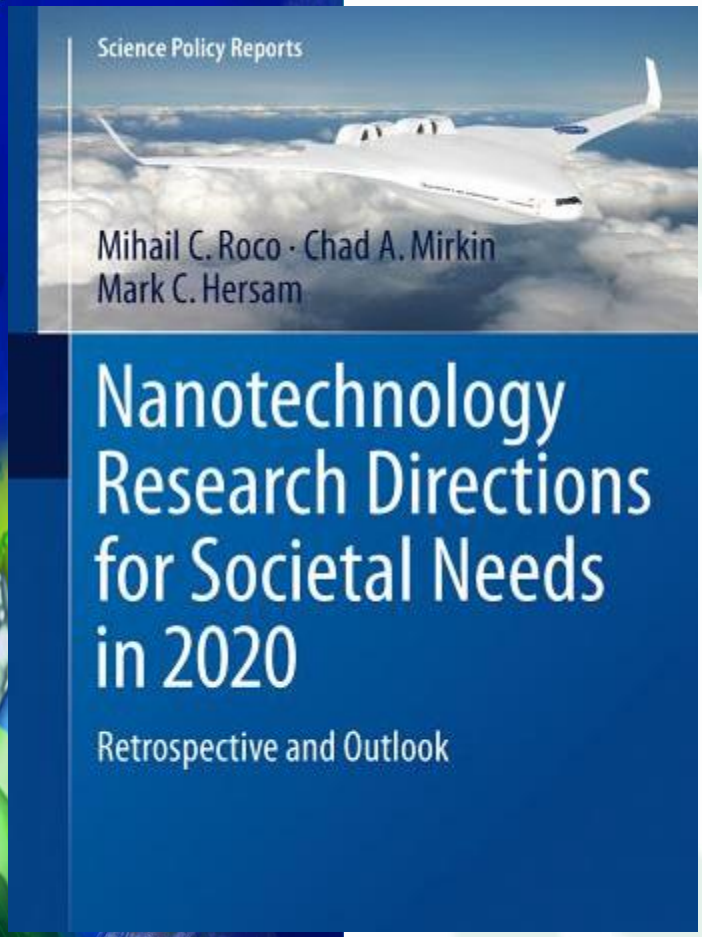
Program Component Areas:

1. **Nanotechnology Signature Initiatives**

   Sustainable Nanomanufacturing
   Nanotechnology for Sensors and Sensors for Nanotechnology

2. Foundational Research
3. Nanotechnology-Enabled Applications, Devices, and Systems
4. Research Infrastructure and Instrumentation

5. **Environment, Health, and Safety**



Nanotechnology research moves to sustainability

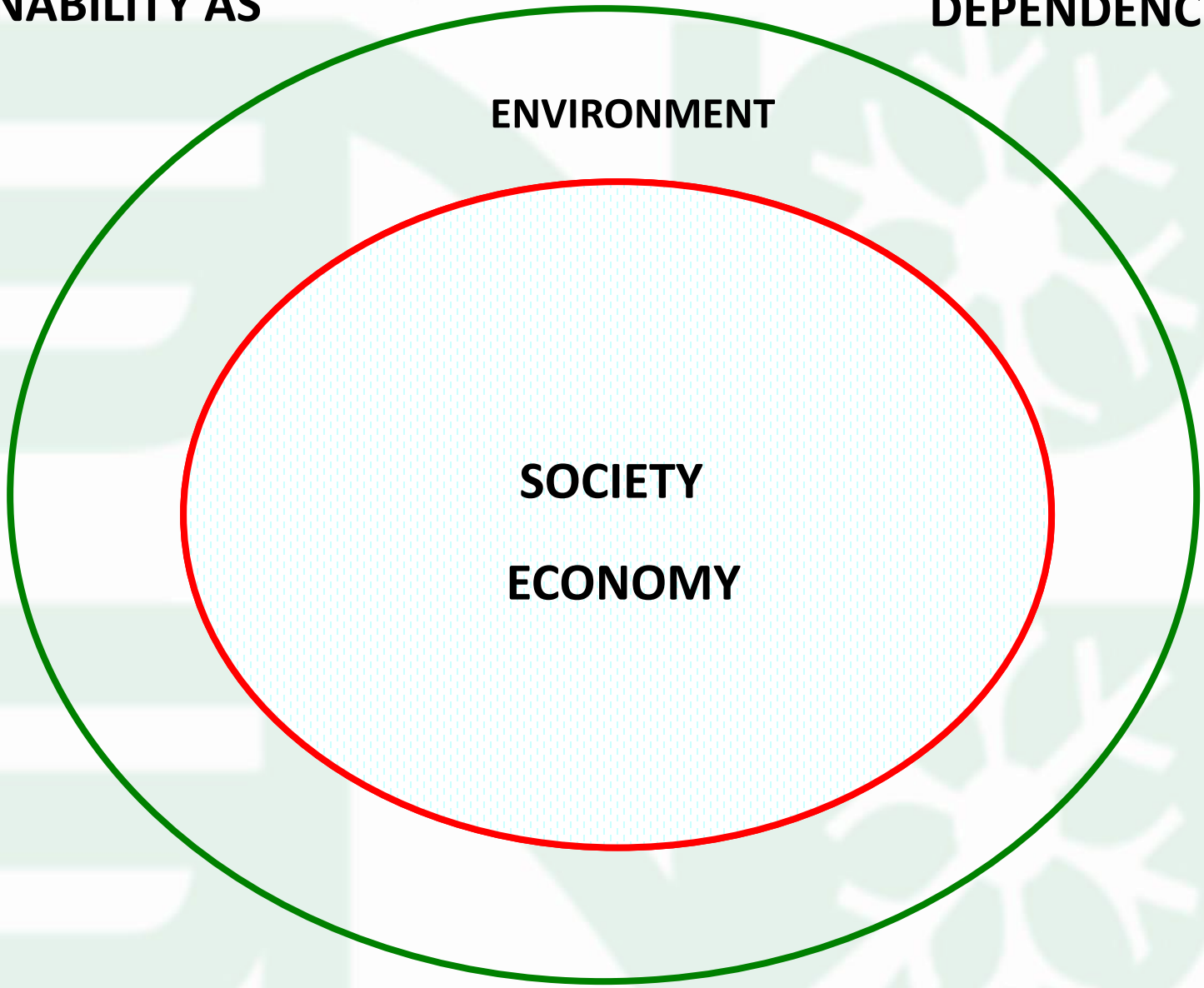
Safe and sustainable development of nanotechnology for responsible and effective management of its potential; this includes environmental, health, and safety (EHS) aspects and support for a sustainable environment in terms of energy, water, food, raw materials, and climate

What is Sustainability?

- "Development that meets the needs of the present without compromising the ability of future generations to meet their needs" [1]
- "The reconciliation of society's developmental goals with the planet's environmental limits over the long term" [2]
- "Meeting fundamental human needs while preserving the life-support systems of planet Earth" [3]

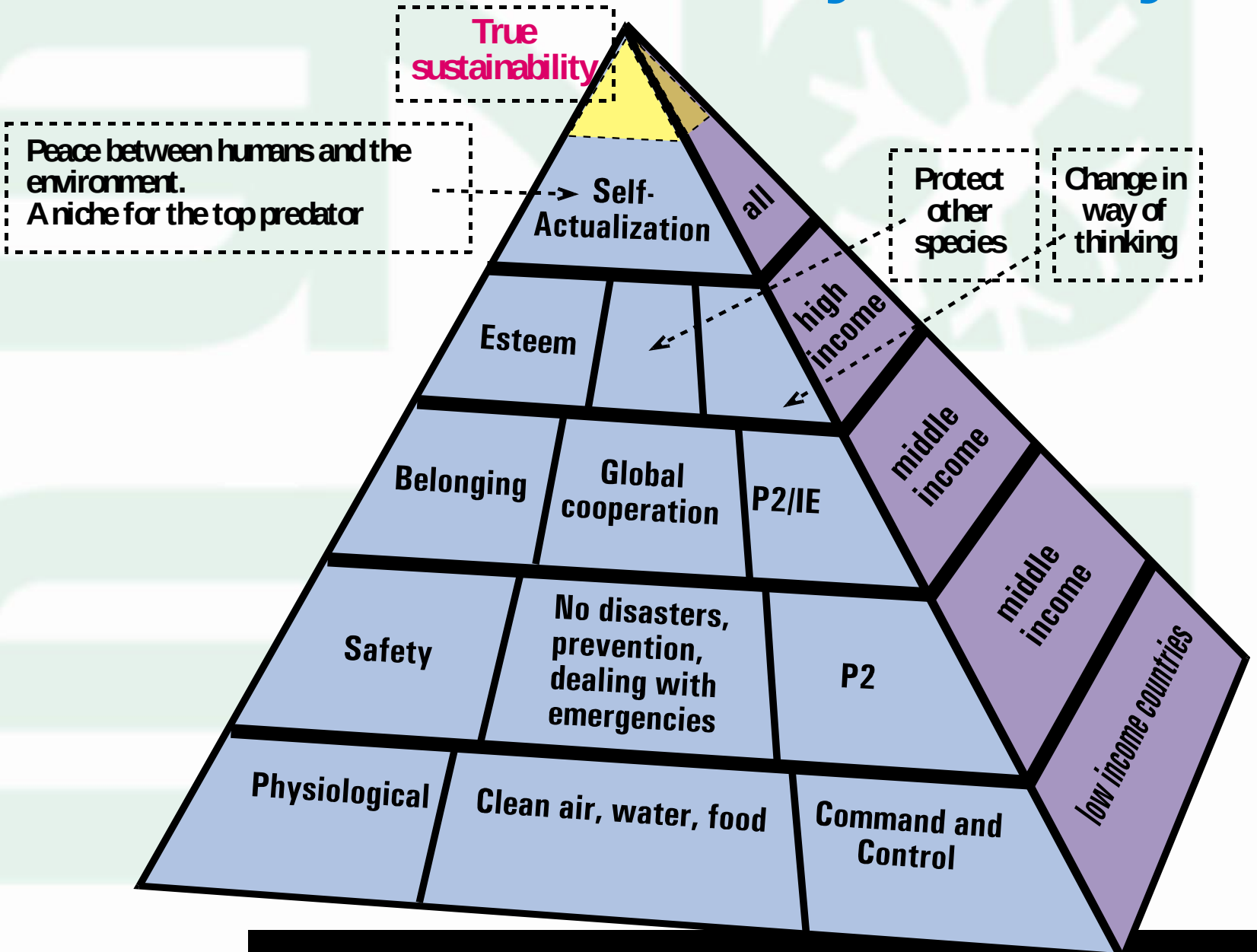
[1.] The Brundtland Report
[2.] NRC, "Our Common Future"
[3.] Kates, RW, et. al., (2001) *Science: 292* pp. 641-642.

SUSTAINABILITY AS DEPENDENCIES



Giddings et al, Sust. Dev.,2002

Maslow/Sustainability Hierarchy



Karn

IPAT Equation

A way to approach the impacts of human activity on the planet...
And approach sustainability

Impact = Population x Affluence x Technology

UN Millennium Development Goals

- Eradicate extreme poverty and hunger
- Achieve universal primary education
- Promote gender equality and empower women
- Reduce child mortality
- Improve maternal helth
- Combat HIV/AIDS, malaria, and other diseases
- Ensure environmental sustainability
- Develop a global partnership for development

Adopted 2000 for 2015

Issues of Sustainability

- Global climate change/Energy
- Depletion of natural resources
  - Water
  - Forest products
  - Minerals
  - Petroleum
- Population-related problems
  - Infectious disease
  - Urbanization and social disintegration
  - Income gaps
- Environmental degradation
  - Pollution
  - Threatened habitats
  - Loss of biodiversity

Example: Sustainability issue Depletion of natural resources

What can nanotech offer?

Water filtration systems for drinking water purification and waste removal

Sensors to detect water pollutants, both chemical and biological

Sensors to manage forest ecosystems

Dematerialization—less use of materials as nanotech enables production of smaller products; less waste in building from bottom up

Move to other fuels such as solar, hydrogen
More efficient use of petroleum in materials manufacturing

Business Initiatives moving toward sustainability

ISO 14000

Environmental Management Systems: 14001, 14002, 14004

Environmental Auditing: 14010, 10411, 14012

Evaluation of Environmental Performance: 14031

Environmental Labeling: 14020, 14021, 14022, 14023, 14024, 14025

Life Cycle Assessment: 14040, 14041,14042, 14043

GRI

The Global Reporting Initiative (GRI) is a multi-stakeholder process and independent institution whose mission is to develop and disseminate globally applicable Sustainability Reporting Guidelines. These Guidelines are for voluntary use by organizations for reporting on the economic, environmental, and social dimensions of their activities, products, and services. The GRI incorporates the active participation of representatives from business, accountancy, investment, environmental, human rights, research and labor organizations from around the world. Started in 1997 by the Coalition for Environmentally Responsible Economies (CERES), the GRI became independent in 2002, and is an official collaborating center of the United Nations Environment Programme (UNEP) and works in cooperation with UN Secretary-General Kofi Annan's Global Compact.

Societal issues (GRI)

Employment

Labor/Management relation

Occupational Health and Safety

Training and Education

Diversity and Equal Opportunity

Sustainable Nanotechnology Organization

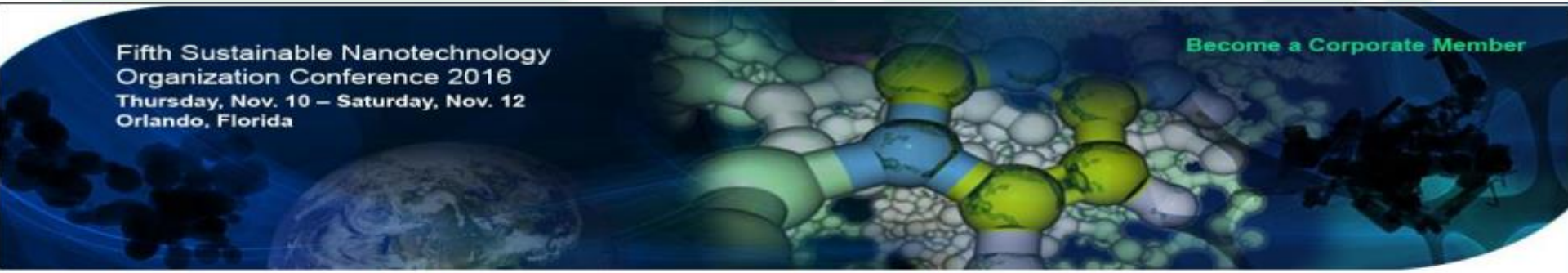
Research | Education | Responsibility

The Sustainable Nanotechnology Organization (SNO) is a non-profit, worldwide professional society comprised of individuals and institutions that are engaged in:

- Research and development of sustainable nanotechnology
- Implications of nanotechnology for Environment, Health, and Safety
- Advances in nanoscience, methods, protocols and metrology
- Education and understanding of sustainable nanotechnology
- Applications of nanotechnology for sustainability

SNO's purpose is to provide a professional society forum to advance knowledge in all aspects of sustainable nanotechnology, including both applications and implications.

WWW.SUSNANO.ORG



What: 5th Sustainable Nanotechnology Organization Conference

Theme: Sustainable Nanotechnology Systems

Where: Orlando, Florida
DoubleTree by Hilton Universal
When: Thursday, November 10 to Saturday, November 12, 2016

Sustainable Nanotechnology through systems And systems of systems

1.Food/agricultural systems: Precision agriculture; pesticide delivery, nutrient delivery, improved food packaging and preservation; food fortification; stabilizing soil; human health and environmental implications.

2.Energy systems: Energy storage; generation by solar and wind; energy transmission; CO2 capture and storage; plant efficiency improvements; system controls; air pollution control in fossil systems

3.Air/Water systems: Drinking water treatment; air pollution controls, wastewater treatment; groundwater remediation; pollution prevention; disinfection; decreasing the energy footprint of water treatment; distribution systems; source water protection; lowering demand for water in industry and households, air filtration systems.

4.Industry/Manufacturing (in general, not just nanomanufacturing) systems: Lowering process energy requirements; using more benign materials; safety of nanomaterials compared to alternatives; substitution for renewable resources; pollution prevention; monitoring systems for manufacturing; lifecycle releases of nanomaterials and models to predict exposure concentrations; economic sustainability of nanotechnology.

5.Solid waste (especially E-waste) systems: Recycling of nanomaterials; resource recovery from landfills; improved quality of recycled materials; advanced waste management

A more holistic approach to sustainability using nanotechnology

6. Environmental/Biological systems: Ecotoxicity; ecosystem responses to nanomaterial releases; improved monitoring tools, exposure routes and exposure models for consumers and the environment; models for environmental fate and exposures of nanomaterials.
7. Health/medical systems: Diagnostic tools for healthcare; nanomedicine and improved drug delivery; models for nanotoxicity prediction/reduction
8. Urban systems: Improving construction materials; building more sustainable residences and commercial buildings; improving energy systems for heating and cooling; improving transportation systems (including increasing fuel efficiency; decreasing weight of vehicles; building better catalysts)
9. Education systems: Curriculum development for sustainable nanotechnology, case studies, materials development, informal education networks
10. Social systems and governance: Upcoming laws and regulations; systems of governance of nanomaterials; social justice concerns; education; calculating and communicating benefits (and risks) of nanotechnology

…And systems of systems

e.g., Food, Water, Energy, Natural Ecosystems

Systems comprising sustainability

Energy

(Climate change due to gases emitted during energy production)

extraction → transportation → Production

Production → use

use → End of Life

Where does sustainable nano fit in?

Nanotech Sustainable Energy Enablers

1. Photovoltaics -- drop cost by 100 fold.
2. Photocatalytic reduction of CO_2 to methanol.
3. Direct photoconversion of light + water to produce H_2.
4. Fuel cells -- drop the cost by 10-100x + low temp start + reversible
5. H_2 storage -- light weight materials for pressure tanks and LH2 vessels, and/or a new light weight, easily reversible hydrogen chemisorption system (material X).
6. Batteries, supercapacitors, flywheels -- improve by 10-100x for automotive and distributed generation applications.
7. Power cables (superconductors, or quantum conductors) with which to rewire the electrical transmission grid, and enable continental, and even worldwide electrical energy transport; and also to replace aluminum and copper wires essentially everywhere -- particularly in the windings of electric motors and generators (especially good if we can eliminate eddy current losses).

Smalley, 2004

Nanotech Sustainable Energy Enablers

8. Nanoelectronics to revolutionize computers, sensors and devices.
9. Nanoelectronics based Robotics with AI to enable construction maintenance of solar structures in space and on the moon; and to enable nuclear reactor maintenance and fuel reprocessing.
10. Super-strong, light weight materials to drop cost to LEO, GEO, and later the moon by > 100 x, to enable huge but low cost light harvesting structures in space; and to improve efficiency of cars, planes, flywheel energy storage systems, etc.
11. Thermochemical catalysts to generate H_2 from water that work efficiently at temperatures lower than 900 C.
12. Nanotech lighting to replace incandescent and fluorescent lights
13. NanoMaterials/ coatings that will enable vastly lower the cost of deep drilling, to enable HDR (hot dry rock) geothermal heat mining.
14. CO_2 mineralization schemes that can work on a vast scale, hopefully starting from basalt and having no waste streams.

Smalley, 2004

What we need to consider in the future in Sustainable Nano

There have been no show stoppers

Nanotechnology is not yet institutionalized in academia

Politicians get bored or need something new

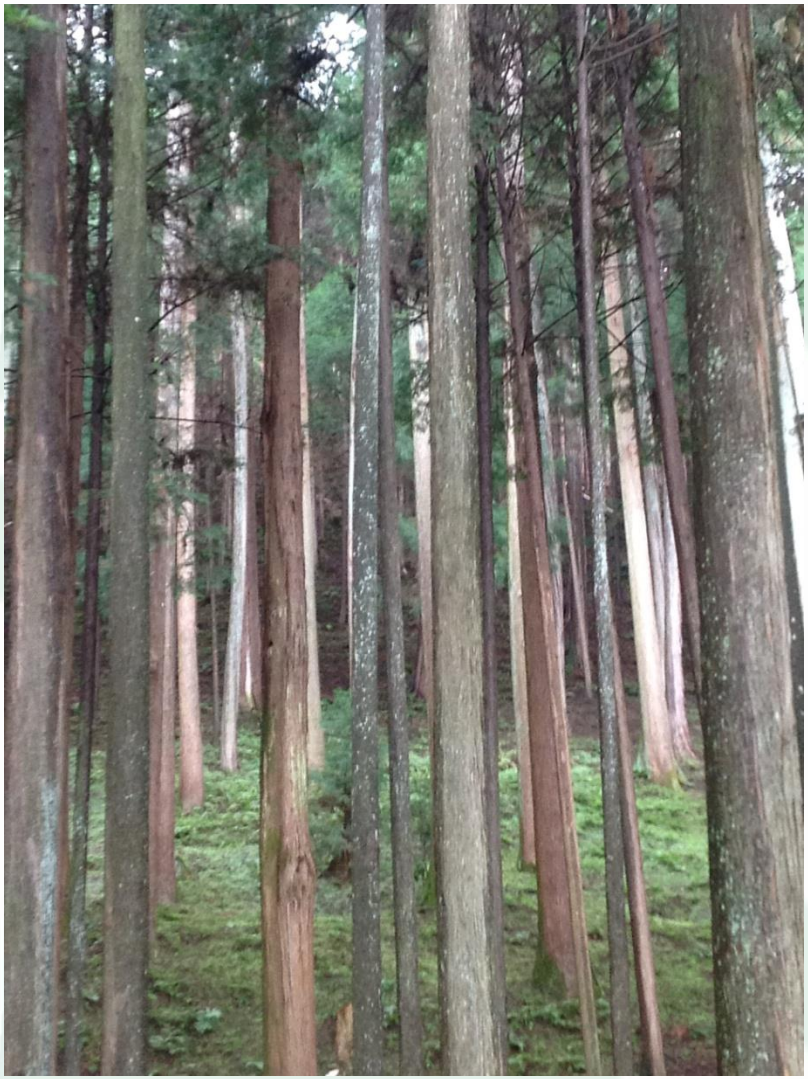
Repackaging is not immoral

We still need strong champions

Paradigm shifts and philosophical changes do not come often in a lifetime

Scientists and Engineers have a greater responsibility to practice sustainable nanotechnology

…because they can



Thanks!

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"When you fully understand the situation, it is worse than you think"
Barry Commoner