

# Nanotechnology and Sustainability

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**[www.epa.gov/ncer/nano](http://www.epa.gov/ncer/nano)**

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a nanometer (nm) is a billionth ( $10^{-9}$ ) meter  
(1000  $\mu\text{m}$  or  $10 \text{ \AA}$ )

# Nanotechnology is...

the ability to work at the molecular level, atom-by-atom, to create large structures with fundamentally new molecular organization.

## Size

Research and technology development at the atomic, molecular or macromolecular levels, in the **length scale** of approximately 1 - 100 nanometer range.

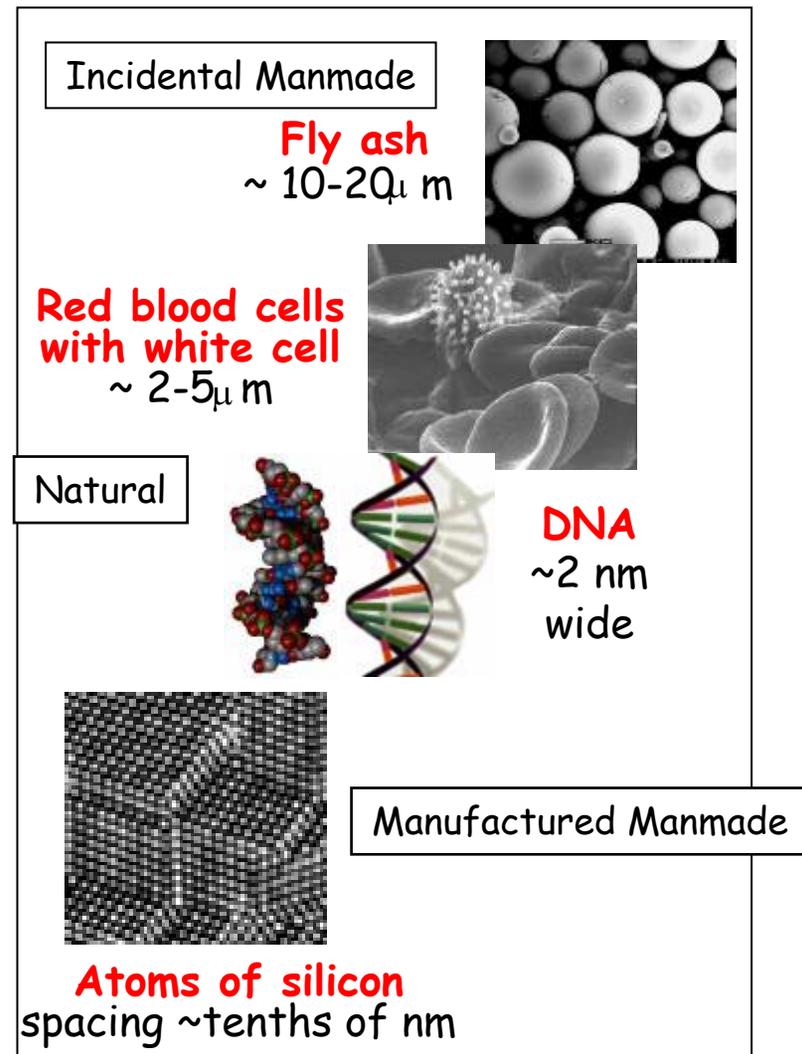
## Structure

Ability to **control or manipulate** on the **atomic scale**.

## Novel properties

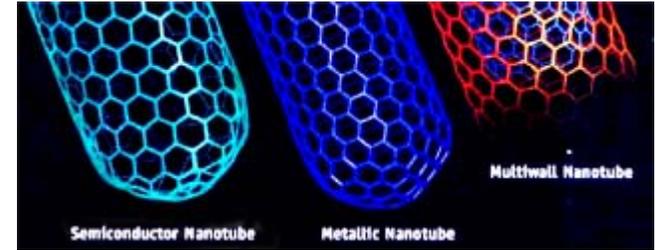
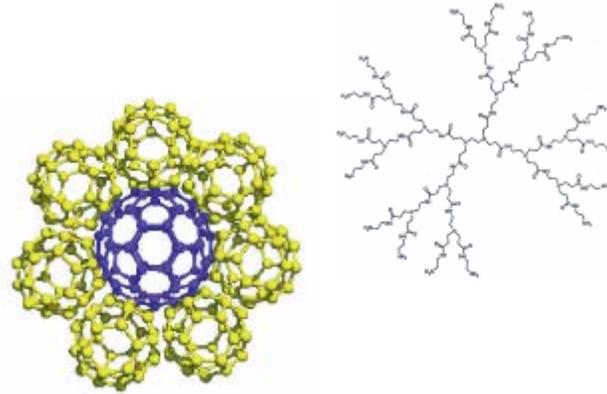
Creating and using structures, devices and systems that have **novel properties and functions** because of their small and/or intermediate **size**.

*The ultimate goal is to build essentially anything from scratch, atom by atom*



## Keep in mind

Nanotechnology does not include just a single material or class of materials



Nanotechnology does not include just a single industry or industrial sector



Nanotechnology converges with other technologies: biotechnology, information technology

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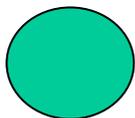
# Stages of Nanotechnology Development

Technological Complexity  
increasing



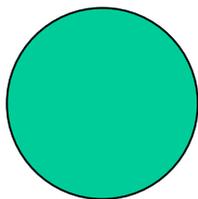
## First Generation ~2001: Passive nanostructures

Nano-structured coatings, nanoparticles, nanostructured metals, polymers, ceramics, Catalysts, composites, displays



## Second generation ~Now: Active nanostructures

Transistors, amplifiers, targeted drugs and chemicals, actuators, adaptive structures, sensors, diagnostic assays, fuel cells, solar cells, High performance nanocomposites, ceramics, metals

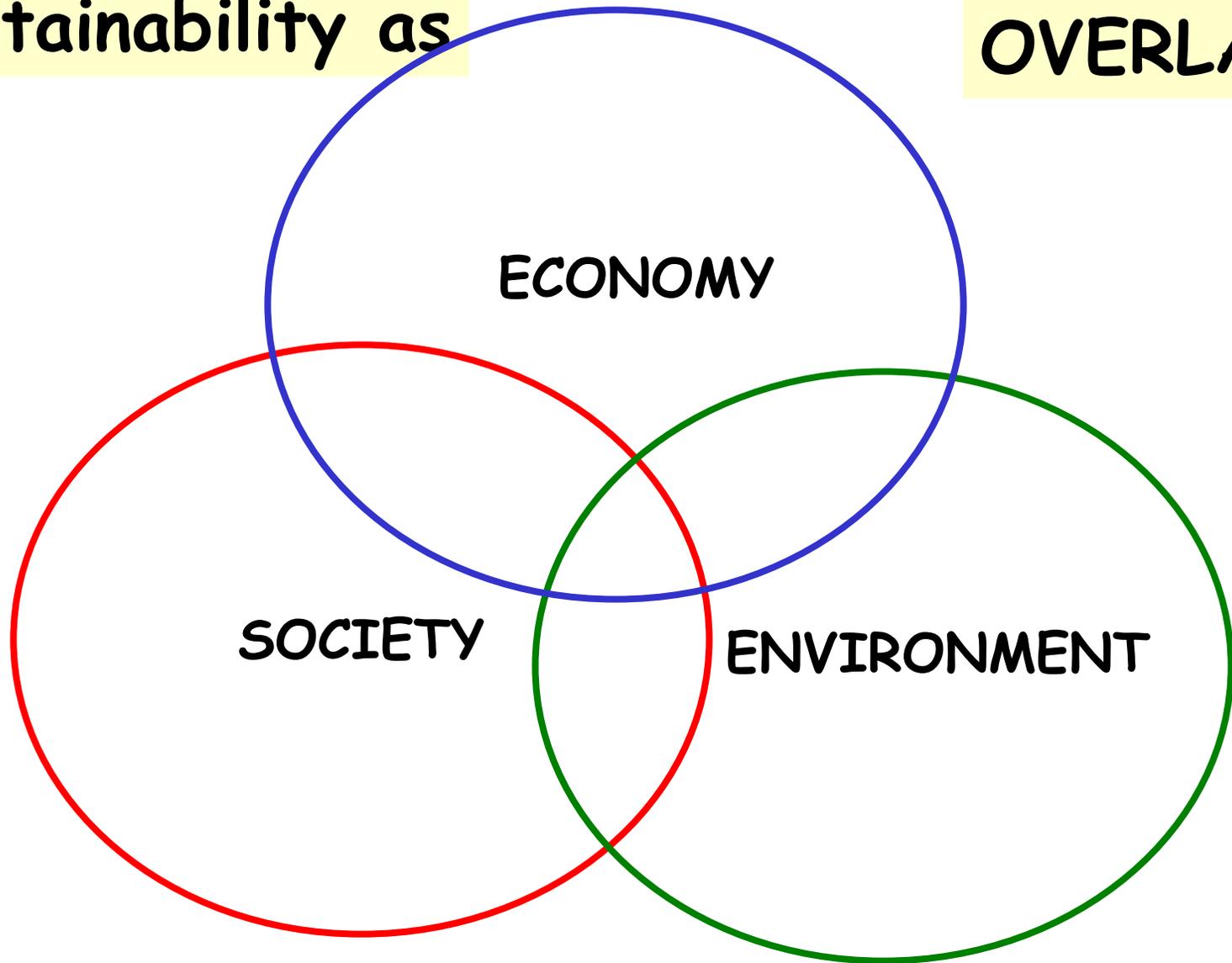


## Third Generation ~ 2010: 3-D nanosystems and systems of nanosystems

Various assembly techniques, networking at the nanoscale and new architectures, Biomimetic materials, novel therapeutics/targeted drug delivery

**Sustainability as**

**OVERLAPS**

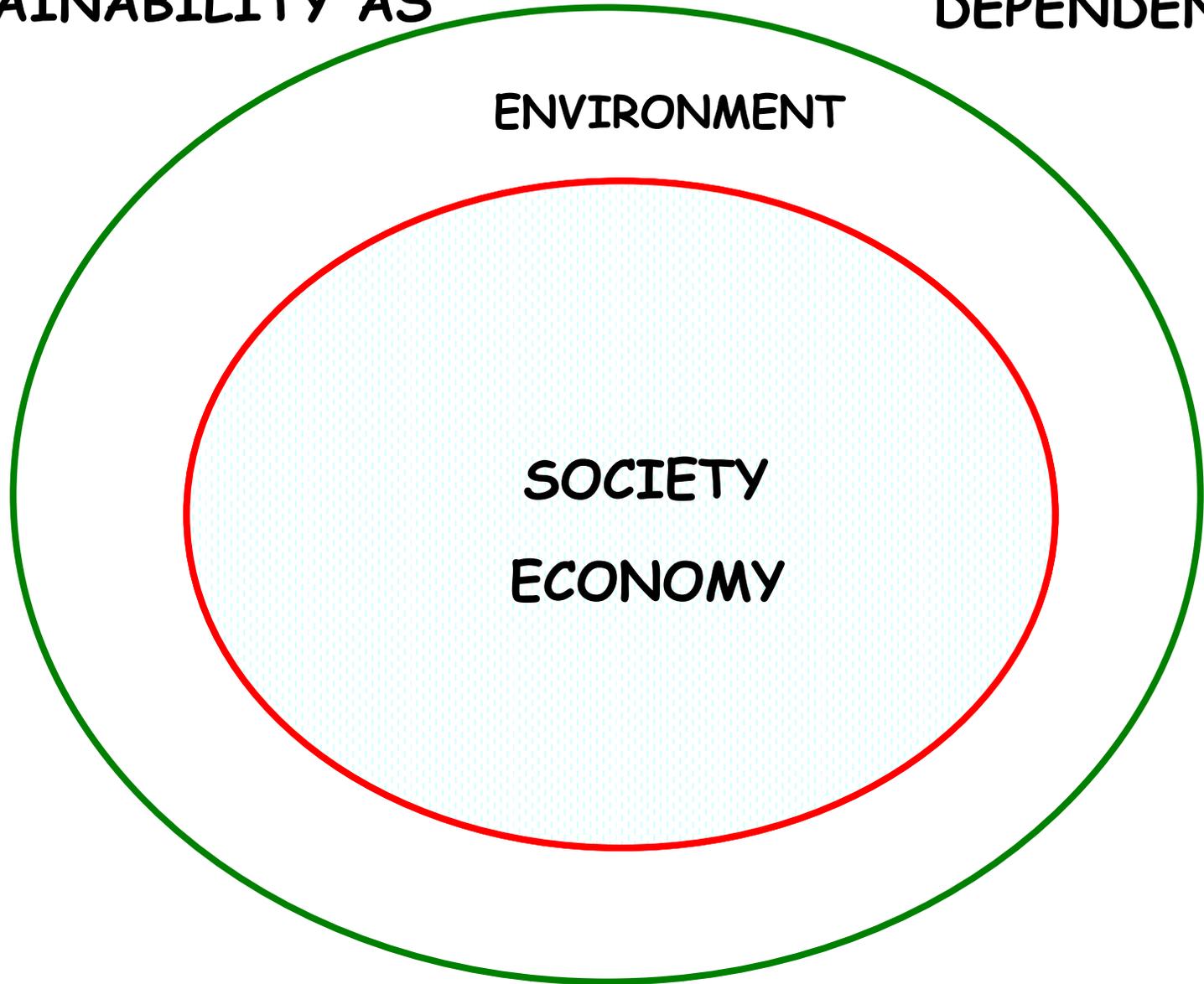


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**SUSTAINABILITY AS**

**DEPENDENCIES**



Giddings et al, Sust. Dev.,2002

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# Issues of Sustainability

- ✿ Global climate change
  - Energy
- ✿ Depletion of Natural Resources
  - Threatened species
  - Threatened habitats
  - Scarcity of resources
- ✿ Population Problems
  - Over-population
  - Disease
- ✿ Environmental degradation
  - Pollution

# Global climate change - Energy

Nanotech lighting to replace incandescent and fluorescent lights

Lighter weight materials—less transportation fuel energy use

Efficient electronics—less electrical energy used

More efficient product manufacturing—less production energy

Cleaner burning fuels due to better prefiltration

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

# Depletion of natural resources

Water filtration systems for drinking water purification and waste removal

Sensors to manage forest ecosystems

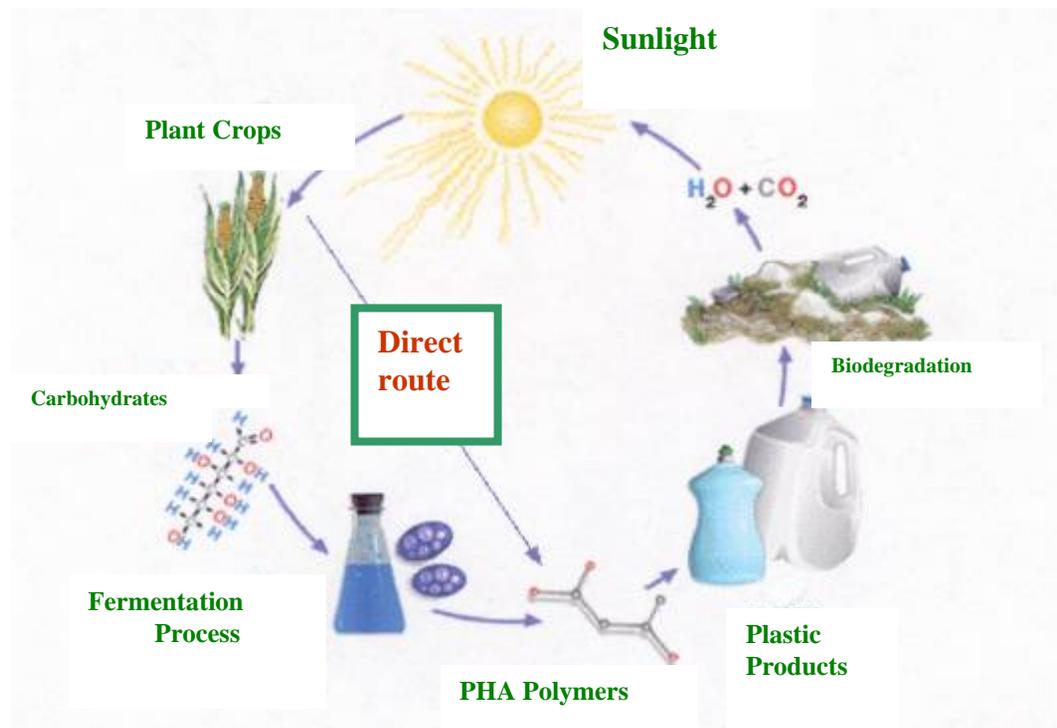
Dematerialization—less use of materials as nanotech enables production of smaller products; less waste in building from bottom up

Sensors to detect water pollutants, both chemical and biological

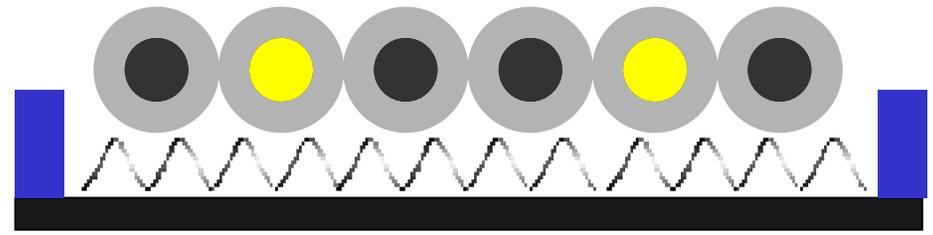
Move to other fuels such as solar, hydrogen  
More efficient use of petroleum in materials manufacturing



**Microwave functionalization of nanotubes**  
Reduced reaction time  
number of reaction steps  
Wang, Iqbal, Mitra



**Bacterial polyester nanoparticles**  
Mohanty, Parulekar, Drzal



5 nm

**Biomolecular nanolithography for bottom-up assembly of nanoscale electronic devices**  
Kearns, Hutchison

# But what are the possible down sides?

What are the risks to human health and the environment?

Unknown:

Toxicity



Fate, transport, transformation in the environment

Bioaccumulation in the food chain

Life Cycle impacts

Research is beginning,  
but a much greater effort is needed to keep up with the technology

# The Environment/Human Health Challenge

Use nanotechnology research to:

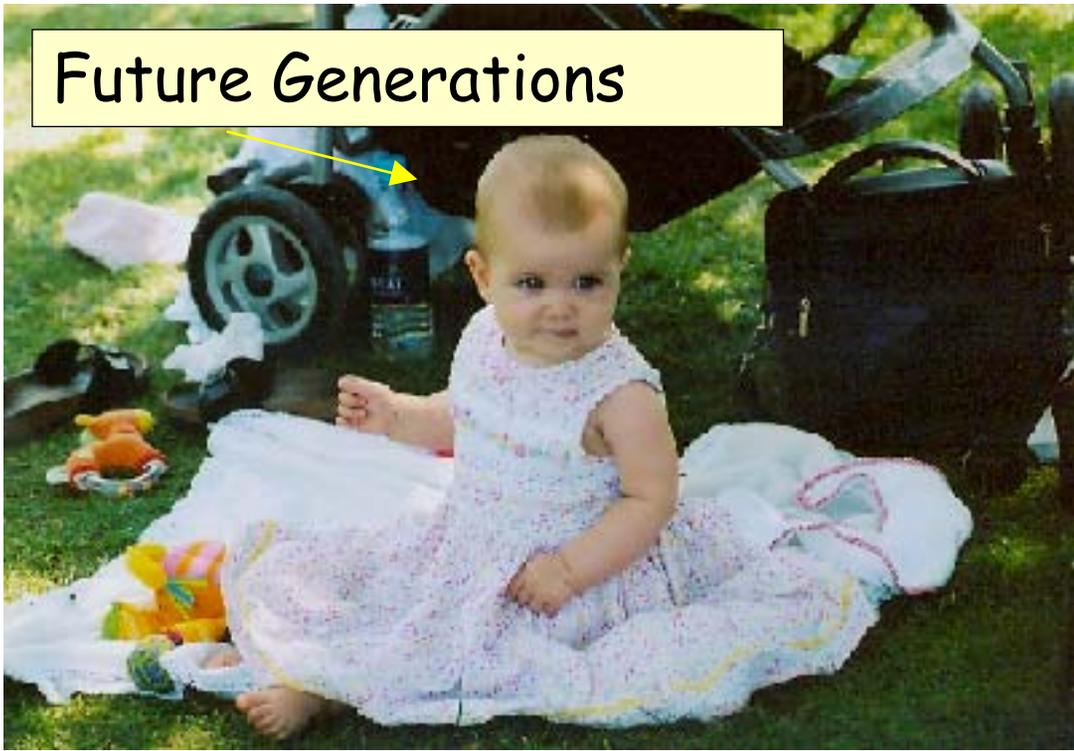
...Help clean up **past** environmental damage

...Correct **present** environmental problems

...Prevent **future** environmental impacts

...Help **sustain** the planet for ...

Future Generations



# Questions??

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Nanotechnology is a very powerful new approach that will change our industries and our lives. We have a very small window right now to bring up this technology responsibly and sustainably—to learn from past mistakes and concurrently look at the possibility of harmful implications as we benefit from the applications.

It's an opportunity too important to neglect.

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