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Nanotechnology: Tiny Particles, Big Shifts

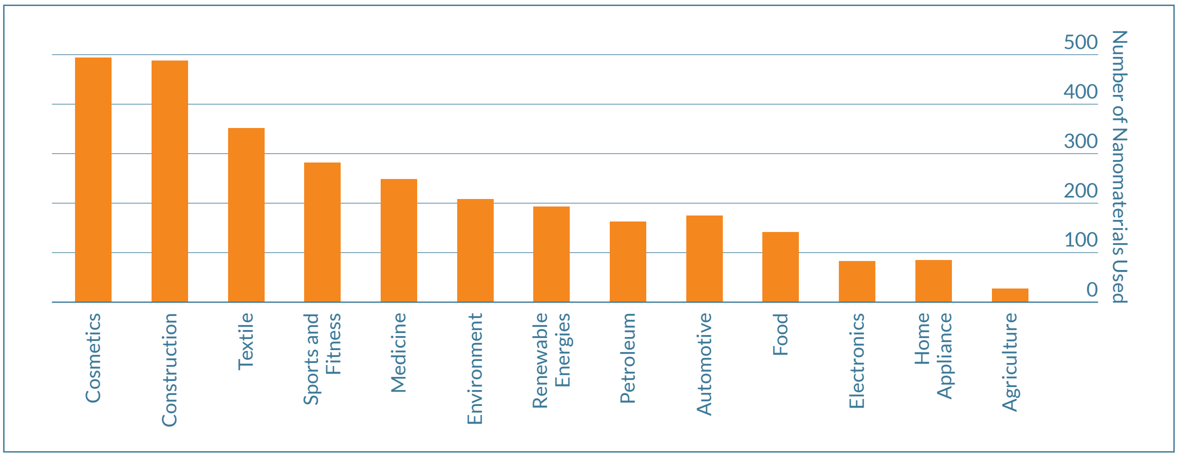
Emerging Risk Categories: *Technological, Environmental, Societal, Economic*
Industries Impacted: *Government, Financial Services, Technology, Consumer Products & Services, Agriculture, Healthcare & Life Sciences, Industrial Products & Services*

Nanotechnology involves the ability to see, control and manufacture materials and devices on the scale of individual atoms and molecules, and even molecular subunits (supramolecular level). Since everything on the planet consists of atoms, the application of nanotechnology is far-reaching. As scientists and engineers find ways to manipulate materials at the nanoscale to take advantage of enhanced properties, such as higher strength or lighter weight, many possible applications suggest themselves across multiple industries.

Nanoscience has been evolving since 1959, when physicist Richard Feynman introduced the concept of manipulating atoms on an infinitesimal scale of 10-9 meters (aka nanoscale). Since then, scientists in all fields — chemistry, biology, physics, material science, engineering, etc. — have been designing structures and systems to perform these manipulations. Configurations on a larger scale are constricted to certain properties of atoms, such as weight, strength, reactivity and response to light; however, at the nanoscale, these structural properties can be altered to increase a material's usefulness, advancing societal needs. These extremely small structures can be used for anything, from increasing the strength of sporting equipment to delivering drugs to diseased cells in a person's body.

Over the past several decades, nanotechnology has become increasingly relevant. The nanotechnology market is estimated to reach US$12.83 billion by 2021, demonstrating the promising nature of nanostructures. While the U.S. is currently the largest market for nanotechnology, the Asia-Pacific region, Brazil and Canada are all poised for considerable growth in the coming years due to favourable microeconomic conditions and investments.

Use of Nanomaterials by Industry



Source: Nanotechnology Products Database, StatNano, 2016: product.statnano.com/.

Nanoparticles Timeline

1959	Richard Feynman gives the first lecture on nanotechnology and engineering at the atomic scale, presented at the annual meeting of the American Physical Society at CalTech.
1981	A microscope for imaging matter at an atomic level is developed.[1]
1990s	First nanotechnology companies emerge.
2000	President Clinton launches the National Nanotechnology Initiative to coordinate federal research and development efforts.
2012	The United States plans to spend nearly $2 billion on nanotechnology research.[2]
2015	Nanotechnology market reaches $4.49 billion.[3]
2016	The Nobel Peace Prize in Chemistry is awarded to scientific discoveries in nanotechnology — the design and synthesis of molecular machines.[4]
2021	The nanotechnology market is estimated at $12.83 billion.[3]

1 www.britannica.com/technology/scanning-tunnelling-microscope

2 fas.org/sgp/crs/misc/RL34401.pdf

3 www.prnewswire.com/news-releases/nanotechnology-market-to-reach-1283-billion-usd-by-2021---industryarc-analysis-588366601.html

4 www.nobelprize.org/nobel_prizes/chemistry/laureates/2016/

Key Considerations and Implications

As with any rapidly evolving field, new applications for nanotechnology are appearing constantly, along with considerations regarding the future of the technology. Among them:

- **Regulation** — Due to the variety of nanotech applications, supervision of nanotech research can be very complex and difficult to apply. Care must be taken not to strangle a burgeoning field with regulation, while providing a safe environment for beneficial research across many different fields.
- **Transparency** — Nanotechnology may be used in controversial applications, such as surveillance instruments, miniature guns and explosives, or weapons with the ability to attack physical structures or biological organisms at the molecular level. The technology is not visible to the naked eye, raising concerns of the ability to easily monitor the use of these new applications and provide an appropriate quality control framework. On the sensational end of the spectrum, some have expressed concern that self-replicating nanobots can wreak havoc on Earth if they are not properly controlled.
- **Privacy and consent** — In healthcare, applications of nanotechnology may represent forms of invasive medicine, raising issues such as appropriate disclosures, patient consent and privacy. Such issues need to be considered early on, before widespread application of the technology in the medical field.
- **The environment** — The energy industry could experience huge advantages from applications of nanotechnology that can produce fossil fuels more efficiently, as well as spur the production of a number of "green" fuels. In addition, nanotech applications in controlling water pollution could greatly alter environmental risk assessments, enabling approvals of oil extraction and other controversial projects. This, in turn, could shift the weight of environmental concerns from production methods and water pollution to other risks, such as carbon emissions.

Spotlight: Industry Applications of Nanotechnology

Nanotechnology is already being used by consumers in everyday products, such as stain-resistant clothing, stronger, thinner and lighter bottles and packaging, and stronger tennis balls and rackets. Below are examples of other applications across industries:

HEALTHCARE	Researchers have developed prototypes of nano-sized robots that can be used to deliver drugs to diseased cells or remove foreign objects in the human body. Drugs themselves can be produced on a nanoscale to allow for minute targeted doses, and DNA-delivering nanoparticles can alter the course of diseases such as cancer by attacking them on the cellular level, reducing dependence on more toxic treatments, such as radiation and chemotherapy. Additionally, the current wave of antimicrobial resistance could be combated if current research projects using nanotechnology prove successful.
ENERGY/FUELS	Shortages in diesel and gasoline can be mitigated using nanotechnology to produce fuel from raw materials more efficiently and at lower cost. Additionally, nanofibres can replace conventional electrodes to greatly improve the performance of hydrogen fuel cells in cars, paving the path for sustainable clean energy vehicles.
WATER TREATMENT	Nanoadsorbents, such as carbon nanotubes, are solid substances that can be used to remove both organic and inorganic pollutants from water. Nanometals can help reduce industrial contaminations caused by arsenic and heavy metals through a chemical reaction process, instead of traditional pumping and treatment of water. Other nanoparticles can act as membranes to remove virus cells, salt and metals from unsafe water to make it drinkable.

ELECTRONICS

Nanoelectronic devices can create better displays and memory chips, all while decreasing their size and power usage. Nanotechnology can also be applied to batteries to make them less flammable, more powerful and easier to charge. It can also extend shelf life dramatically by using nanomaterials to separate the liquid from the solid electrodes when the battery is not in use.

FOOD INDUSTRY

Nanotechnology in food packaging can be used to alert consumers to contaminated food by turning the package a different colour once bacteria enters the package. Another food application is nanoencapsulation, a nanoscale-sized coating used to mask the taste and smell of certain additives to foods.

Where to Learn More

"Nanorobots: Where We Are Today and Why Their Future Has Amazing Potential," by Peter Diamandis, Singularity Hub, May 16, 2016: http://singularityhub.com/2016/05/16/nanorobots-where-we-are-today-and-why-their-future-has-amazing-potential/.

"From Super Pills to Second Skin: Meet the Willy Wonka Revolutionising Medicine," by Amy Fleming, *The Guardian*, October 17, 2016: www.theguardian.com/lifeandstyle/2016/oct/17/robert-langer-nanotechnology-pioneer-willy-wonka-revolutionising-medicine.

"Nanomedicine To Combat Infections From Antimicrobial-Resistant Bacteria." Article published by Nicolas Gouze, ETPN Secretariat in the publication 'International Innovation' (Issue 140): www.etp-nanomedicine.eu/public/about-nanomedicine/nanomedicine-applications/amr.

"Nanotechnology & You," Nano.gov: www.nano.gov/you/nanotechnology-benefits.

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