Nanotechnology and the S&P 500:

Small Sizes, Big Questions

By Susan L. Williams

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Acknowledgments

Authored by

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About the Author

Susan Williams has more than 30 years of research experience concerned with energy, environmental and corporate responsibility topics for institutional investors. Since 2009, Williams has been an independent consultant focused on sustainability and energy issues for Si2 and People 4 Earth Foundation. She previously was a research manager at RiskMetrics Group and began her career with IRRC in 1984, after consulting for energy and environmental firms in the Boston area.

Williams is the lead author of more than a half-dozen books and publications, including a 10-year series about U.S. renewable energy development. Her findings have been reported in *The Wall Street Journal, The New York Times, The Washington Post*, the *Economist* and elsewhere. She also has published work on environmental issues such as hydraulic fracturing of natural gas, large-scale hydroelectric development in northern Quebec and recycling, and has contributed to various journals, including *Issues in Science and Technology*. In addition, Williams has covered a range of other social, economic and corporate governance topics.

She graduated *cum laude* with a B.A. in American Studies from Williams College, with highest honors from the Environmental Studies Program.

Additional Contributors

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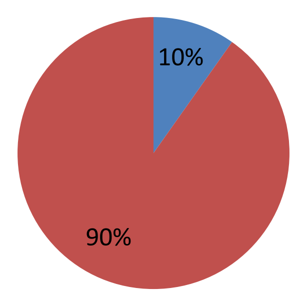
Executive Summary

Companies worldwide have begun capitalizing on what could become a $3 trillion global market that presents investors with tremendous opportunities as well as undefined environmental, health and safety risks. Nanotechnology has been developing rapidly, but has been largely unnoticed by the general public. At least 1,600 consumer products have entered the marketplace in the last eight years alone, and this is just a sliver of the products and processes already in use and under development—all of which are measured in units some 90,000 times smaller than the width of a human hair. By 2020, six million people worldwide may work with nanomaterials, revolutionizing healthcare, information technology, energy systems and other fields. Corporations now provide about half the funding for research on nano frontiers, catching up with governments led by the United States (with $21 billion invested since 2001) and 60 other countries, most prominently Germany, France, Japan, Korea and China.

Nano Disclosures by S&P 500 companies



However, less than one-tenth of S&P 500 companies report to shareholders and other stakeholders on their involvement in nanotechnology. Nanotechnology's promise is tethered to unique environmental, health and safety (EH&S) risks. These stem from the fact that compounds at the nanoscale pose singular and, in many cases, not well understood risks to human health and the environment. At the same time, some environmentalists and shareholders eyeing rapid commercial growth with minimal regulation are questioning whether nanotechnology is on a responsible development path, and whether companies and their shareholders are risking their brand names and could face future liabilities. Most government agencies believe it is premature to issue regulation specific to nanotechnology until more data is gathered and analyzed. Rather than wait for regulation, shareholders are engaging companies in discussions about nano-related EH&S risks and brought to a vote in 2014 the first nano-related shareholder resolution—often a bellwether of social concerns. Concerned investors are promising to step up their efforts in 2015.

With regulators not yet in a position to significantly reduce risks associated with nanotechnology development, the onus falls on companies and their investors to understand, clearly communicate and properly manage the risks and benefits of their nano products and systems. If companies meet the challenge, they will provide substantial long-term financial rewards to investors, and in some instances, unlock cures to many modern ills. Failure could compromise that bright vision of the future.

Structure of this Report

Key issues: This report identifies key issues for investors to consider regarding companies that use and develop nanotechnology and nanomaterials (pp. 11-12).

Current disclosure: We summarize the current state of disclosure by S&P 500 companies (pp. 13-20). Specific disclosures are reproduced in the report appendices (pp. 55-88).

Development of the field and market: A section on products and processes sketches out the 30-year-old development of the nanotechnology field in the United States and the key areas that appear most promising. It also presents available estimates on the size of investments to date and the potential market in the near future, noting the particular challenges in obtaining accurate data (pp. 21-25).

Environmental, health and safety: The report presents the currently identified range of risks to humans and the environment and efforts to beef up EH&S research, including voluntary codes, frameworks and collaborations (pp. 26-36).

Regulation: A section on regulation sets out the questions in play about appropriate regulatory regimes and notes the distinctive strategies underway in Europe and the United States, outlining the relevant EU and U.S. laws and policy principles released by the White House Office of Science and Technology (pp. 37-51).

Shareholder engagement: The report concludes by noting shareholder proposal disclosure efforts begun in 2008 by concerned shareholder groups, including the As You Sow Foundation, Calvert Investments and members of the Interfaith Center on Corporate Responsibility (pp. 52-54). (The 2014 shareholder resolution at **Dunkin' Brands** earned 18.6 percent support, a respectable showing for a first-year resolution.)

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Findings

Nanotechnology is an emerging field that focuses on the understanding and control of matter at near-atomic scale. The nanoscale ranges between 1 and 100 nanometers. One nanometer measures one billionth of a meter. To provide some context, a sheet of newspaper is about 100,000 nanometers thick. While nanotechnology focuses on extremely small materials, its reach is quite broad. Nanotechnology crosses scientific disciplines, can be employed in many fields of research and has the potential to affect virtually every aspect of daily life and impact every economic sector.

To date, nanotechnology often has enabled improvements in existing products and systems—making them stronger, lighter, water-repellent, anti-reflective, antimicrobial or scratch-resistant, to name a few characteristics. Nanotechnology's greatest promises will be achieved, however, as it moves beyond the currently dominant phase of passive nanomaterials and nanostructures, such as engineered nanoparticles like carbon nanotubes, to an active phase of nanostructures, nanosystems and nano devices that change their state during operation. This next phase could lead to more revolutionary types of science and applications with tremendous societal and economic benefits. Detection and treatment of cancer and widespread chronic diseases, environmental remediation and advances in energy systems are just a sampling of nanotechnology's potential offerings.

Scientists have made great strides in understanding the nanoscale over the last 20 years, but there remains a considerable amount scientists do not understand. As David Stepp, a Division Chief in the U.S. Army Research Office, pointed out in a June 2013 national nanotechnology workshop, outstanding questions include "Can we make exactly what we want at the nanoscale? Can we measure it and really characterize exactly what we think we made? And can we actually model that?"[1]

Fundamental properties of matter change at the nanoscale. Unique physical, chemical, mechanical and optical properties of materials can occur that do not occur with the same material's larger counterparts or even with single atoms or molecules. Nanosilver, for instance, has different properties from traditional silver. At the nanoscale, the laws of classical physics give way to quantum effects that rule the behavior and properties of particles. Other physical effects, such as the larger surface-area-to-mass ratio that increases reactivity, also come into play.

The very unique properties that make nanomaterials so useful, innovative and full of potential also pose unique risks that are not yet fully understood. There is not yet even a universally accepted definition of nanotechnology or nanomaterials. Concerns about the effects of nanomaterials on human health stem from the fact that a majority of biological processes, including the inner workings of cells, also occur at the nanoscale. Still others are concerned about possible bioaccumulation of nanomaterials in the envi-

[1]Stepp, D., (June 11, 2013). Session 3: Report Back and Synthesis Conversation at 2013 NNI Strategic Planning Stakeholder Workshop. [Video] Retrieved from http://www.tvworldwide.com/events/nnco/130611/default.cfm?logout=1

ronment and the difficulty of recapturing nanomaterials should future scientific studies warrant such action. While some tout nanotechnology as the next industrial revolution, others point to the remediation efforts still underway to clean up the first industrial revolution and question whether we are doing enough to avoid unintended or unwelcome consequences of nanotechnology that could prove even more difficult to remediate.

Societal acceptance of these technologies will be critical to their success. General recognition of this point has led to substantial research efforts around the world to fill knowledge gaps and to better understand the properties and toxicological impacts of nanoparticles. Companies, researchers, government agencies and NGOs are working individually and collaborating on such research. As a result, investment in environment, health and safety (EHS) as a percent of overall investment in nanotechnology has picked up in recent years, as has EHS as a topic in publications and papers on nanotechnology.

Moving too fast?—While all agree on the need to better address EHS issues, a split occurs as to whether more robust EHS research should precede commercialization of nano products. Hundreds of nano products already are in the marketplace, and this ever advancing technology yields new discoveries on a regular basis. Entities such as the Organisation of Economic Co-operation and Development (OECD), large corporations including DuPont, the U.S. President's Council of Advisors on Science and Technology and the European Commission are among those that argue sufficient research and risk assessment exists to warrant moving forward. Commercialization proponents state that while companies, scientists and governments would like to know more about nanomaterials, just as they would like to know more about many other chemical substances, there is more focus on the EHS effects of nanomaterials than there has been with other new chemicals or emerging technologies at a similar stage of development. Moreover, promoters of nanotechnology commercialization point to the recent push on EHS research and say strides are being made on this front. While insufficient information is available to enact regulatory standards, governments are appropriately issuing guidance and following a responsible development path, they say.

Others, such as Friends of the Earth, the Natural Resources Defense Council and As You Sow, a shareholder advocacy group, argue that society is not yet up to the task of assessing, addressing and managing the potential risks of nanotechnology. They say that companies are introducing products into commerce without sufficient risk evaluation and are selling to consumers who have no idea they are purchasing nanomaterials. They also say that while EHS effects may be receiving attention earlier than other chemical substances have historically, researchers and government agencies aren't keeping pace with the number of new products entering the marketplace. These critics contend that researchers and agencies are insufficiently funded, and in many cases lack appropriate oversight authority. They also question whether scientists have yet developed the tools to measure and analyze the full range of nanomaterials' potential impacts. They argue that rather than building an industry and supply chain before nano applications are proven safe, a more prudent course would be for governments to guide away from immediate commercialization so that nanotechnology can reach its full potential in the long term.

Policymakers and regulators worldwide are reassessing regulations and legislation as they scramble to keep up with nanotechnology development. Countries are grappling with the dynamic tension between wanting to lead or participate in what could be the next frontier of global economic development and ensuring that they don't allow unnecessary risks. Failing to address EHS factors could result in harm to humans and the environment, product liability claims, cleanup costs, harm to brand reputation and the public's rejection of nanotechnology. Alternatively, overly restrictive regulations could bar or delay products from entering the market or impose unnecessarily high regulatory compliance costs, rendering countries with such regulations at a distinct disadvantage in the marketplace. The emphasis on speed-to-market is great in this field. Developed countries, such as the United States, could see a resurgence of manufacturing technology based on sophisticated nano applications. Governments also are anxious for nanotechnology to develop to a point where it can address a range of societal and environmental challenges, including purifying water, treating disease and advancing renewable energy technologies.

Questions for Investors

While the debate continues as to whether nanotechnology is on a responsible development path, it is clear that various regulatory agencies are only in the early stages of evaluating the potential risks of nanomaterials to human health and the environment. New nano products entering into commerce while EHS research and related regulations are still evolving may present unknown and emerging risks and potential liabilities. Accordingly, investors may want to undertake their own review to ascertain whether companies have risk management systems in place that are commensurate with their exposure to nanomaterials and/or nanotechnology under development. At present, corporate disclosure on nanotechnology and nanomaterials is minimal and, in some instances, corporations may be unaware if their products contain nanomaterials.

Investor exposure to nanotechnology risks can be broken into two groups of investments: 1) investments in companies that produce and/or sell products that may contain nanomaterials, although nanotechnology is not their primary focus; and 2) investments in companies that have a primary focus or business line to intentionally develop nanomaterials, nanoprocesses or nanosystems.

Nanotechnology Users

Investors may want to pose the following questions to companies that are producing and/or selling products that may contain nanomaterials, even if nanotechnology is not their primary focus:

1. Does the company have publicly available **policies** regarding nanotechnology?
2. Does the company know whether its products **contain nanomaterials**?
3. Does the company **disclose** to the public and consumers whether its products contain nanomaterials?
4. Has the company **reviewed** its use of nanomaterials?
    a. Are they necessary to the product or is there an acceptable alternative with better EHS documentation?
5. Has the company incorporated evaluation of nanotechnology into its **risk management** programs?
    a. Has the company identified its potential liabilities associated with nanotechnology?
    b. Are these potential liabilities addressed in company contracts or various insurance policies?
    c. Does the company have risk management systems commensurate with the level of potential EHS risks it faces from nanomaterials?
    d. Does the company undertake risk assessments and safety testing of nanomaterials?
        i. Is the company assessing risks associated with nanomaterials from a scientific perspective?
        ii. Has the company identified and documented data gaps?
    e. Does the company make its safety testing and risk assessments of nanomaterials transparent?
    f. Does the company assess the full lifecycle of nanomaterials, including raw materials, products, packaging, transportation, and use, reuse, or disposal?

    g. Does the company assess the potential for unintended dispersement (such as nanomaterials shedding from products)?
6. Does the company ask its **suppliers** about the presence of nanomaterials?
    a. Does the company ask its suppliers for similar information on policies, disclosure, testing, risks assessments and lifecycle analysis as noted above?
    b. How does the company insure the integrity of its supply chain with respect to nanomaterials?
7. Does the company participate in nano **initiatives** or use **voluntary codes or frameworks**? Which ones?

Nanotechnology Developers

Regarding companies that have a primary focus or business line to intentionally develop nanomaterials, nanoprocesses or nanosystems, investors may want to ask:

1. Does the company have publicly available **policies** regarding nanotechnology?
2. How is the company **managing** nanomaterials?
    a. Does the company have protocols to ensure no nanomaterials are unintentionally released?
    b. Has the company identified and minimized sources of risk for workers handling products using nanotechnologies?
    c. Does the company have a monitoring system to ensure that its protocols are effective?
3. Has the company undertaken rigorous **safety testing and risk assessments**?
    a. Does the company have adequate resources to evaluate the EHS impacts of its products?
    b. Is the company fully aware of all of the nanomaterials' properties and characteristics?
        i. If not, has the company identified data gaps?
    c. Has the company fully documented the nanomaterials' properties, characteristics and data gaps?
    d. Does the company make its safety testing and risk assessments transparent?
    e. Does the company assess the full lifecycle of nanomaterials and processes, including potential unintended release (such as nanomaterial shedding from products)?
4. What is the **advantage** of the nano application over incumbent technologies or products?
5. Is the company aware of how its nanomaterials or processes will be used by the **end-user**?
    a. How many additional steps are likely in the value chain?
    b. What are the company's potential liabilities with respect to the value chain?
    c. Are these potential liabilities addressed in company contracts or various insurance policies?
6. Does the company utilize voluntary nano **codes or frameworks** or participate in nano **initiatives**? Which ones?

Corporate Disclosure on Nanotechnology

Some 34 S&P 500 companies reported to shareholders that they produce or sell products that either contain nanomaterials, are produced using nanotechnology or are used to develop nanotechnology. Another ten S&P 500 companies reported that they either did not use nanotechnology, were supporting research in or monitoring nanotechnology, using nanotechnology internally or had directors on their boards with involvement in nano firms. Another 18 companies (including two of the 34 noted above) were included in October 2013 in a Nanotechnology Consumer Products Inventory, which uses sources ranging from companies to research papers or media reports. Table A *(next page)* identifies the total of 58 S&P 500 companies that discuss nanomaterials in their Form 10-Ks or corporate responsibility or sustainability reports,[2] or were included in the Nanotechnology Consumer Products Inventory. The table also identifies the focus of discussion in a company's corporate responsibility or sustainability communications. *(Specific disclosures made by listed companies appear in the appendices to this report , as noted in the box, right.)*

Nanotechnology Disclosure by S&P 500 Companies

	Companies	Appendix
Form 10-Ks	27	A
Corporate Responsibility/Sustainability Report	22	B
Nanotechnology Consumer Products Inventory	18	C
Overall Total	58	

10-K Reporting

Si2 identified 27 S&P 500 companies that included references to "nano" in their most recent Form 10-Ks (reviewed in the fourth quarter of 2013).

Risk factors: Six companies reported on risk factors associated with nanotechnology (Item 1A in Form 10-Ks). All six companies—**Altera, Applied Materials, Broadcom, Nvidia, Sandisk** and **Xilinx**—are in the information technology sector and focused on business risks associated with development, production and manufacturing or the ability to successfully utilize or address technological advancements. No S&P 500 company discussed risks associated with environment, health or safety issues.

[2] Si2 reviewed Form 10-Ks for the S&P 500 in the fourth quarter of 2013 for information on nanotechnology. It also looked for the company's latest sustainability or corporate responsibility (CR) report and searched the documents for references to nanotechnology. If the company did not have a standalone sustainability or CR report, Si2 looked at the company's website for sustainability or CR information on nanotechnology. Si2 did not complete this second task if the company had a sustainability or CR report, although it went back in a few high-profile cases to check for additional information. It is possible additional information about nanotechnology may be included in other corporate communications not reviewed for this report.

Business descriptions: Seventeen companies discussed nano products or services as part of their business descriptions (Item 1 in Form 10-Ks). Ten are in the information technology sector, including seven—**Applied Materials, Broadcom, Intel, KLA-Tencor, Lam Research, Linear Technology** and **Xilinx**—that are in the semiconductors & semiconductor equipment industry. Three of these companies also were among the six companies above that identified risks. The remaining three IT companies include **Agilent Technologies**, which highlighted tools, instruments and systems for use in nanotechnology applications; **IBM**, which mentioned it was conducting research in nanotechnology; and **JDS Uniphase**, which is in the communications equipment industry.

Table A:
S&P 500 Company Nano Disclosures

Company	Form 10-K[1]	Responsibility/Sustainability Report or Website[1]	Nanotechnology Consumer Products Inventory[2]
Abbott Laboratories	X		
Agilent Technologies	X		
Air Products & Chemicals	X	Products	
Alcoa	X		
Altera	X		
AMETEK	X		
Apple			X
Applied Materials	X		
AT&T		Internal use	
Avon Products		Disclosure; products; risk assessment	
Becton Dickinson	X		
Broadcom	X		
Cameron International	X[+]		
Carefusion	X[+]		
Celgene		Products	
Coca Cola			X[#]
Colgate-Palmolive*		Disclosure; products do not contain nanomaterials	X
Cummins		Products	
Dow Chemical	X	Products	
E.I. du Pont de Nemours		Support of nano	X
EMC		Monitoring the issue	
Estee Lauder		Disclosure; products; risk assessment	
Ford Motor		Products; risk assessment	
Gap			X
General Mills			X[#]
General Motors			X
Goodyear Tire & Rubber		Risk assessment	
Hershey's			X[#]
Hewlett-Packard		Support of nano; products; risk assessment	
Honeywell			X
Intel	X	Products	X
Intl Business Machines	X[+]	Support of nano; Products; risk assessment	X
J.C. Penney			X

(Table A, continued)

Company	Form 10-K[1]	Responsibility/Sustainability Report or Website[1]	Nanotechnology Consumer Products Inventory[2]
J.M. Smucker			X[#]
Jacobs Engineering Group	X	Products	
JDS Uniphase	X		
Johnson & Johnson		Support of nano; products; risk assessment	
Kellogg			X[#]
KLA-Tencor	X		
Kraft Foods			X[#]
Lam Research	X		
Linear Technology	X		
Lockheed Martin		Support of nano; products	
Merck		Support of nano; products; risk assessment	
Mondelez International		Disclosure; company does not use nanotechnology	
Motorola Solutions			X
Newell Rubbermaid	X		
Nvidia	X		
Pentair	X		
Qualcomm	X		
Sandisk	X		
Stanley Black & Decker			X
Texas Instruments		Risk assessment	
Thermo Fisher Scientific		Products	
Waters	X		
Whirlpool			X
Xilinx	X		
Zoetis	X[+]		

[1]Form 10-Ks and Corporate Responsibility or Sustainability reports were accessed in the fourth quarter of 2013.
[2]Source: Project on Emerging Nanotechnologies (2013). Consumer Products Inventory. Retrieved in October 2013 from http://www.nanotechproject.org/cpi. The Consumer Products Inventory has been compiled by the Project on Emerging Nanotechnologies in the Science and Technology Innovation Program (STIP) at the Woodrow Wilson International Center for Scholars, in collaboration with the Virginia Tech Center for Sustainable Nanotechnology. The inventory contained 1,628 consumer products that have been introduced to the market between 2005 and October 2013.
[+]Form 10-K did not indicate company is producing nanotechnology-enabled product or service.
[*]Colgate-Palmolive reported in its *2012 Sustainability Report* that it does not use nanotechnology in its products.
[#]Companies have been removed from inventory pending a review of their source.

Two companies in the health care sector include a reference to nano in their business description. **Abbott Laboratories** discussed Xience nano™, part of its drug-eluting stent franchise, and **Waters** discussed a nano system in its discussion of its analytical tools and instruments. Another two companies—**Alcoa** and **Dow Chemical**—are in the materials sector, while **AMETEK** and **Jacobs Engineering** are in the industrials sector. Alcoa noted that it is commercializing self-cleaning coatings for building products, and Dow listed a nanofiltration element as part of its Water and Process Solutions. AMETEK pointed out that its analytical instruments are used in nanotechnology research, while Jacobs Engineering noted that its advanced technology clients require highly specialized buildings, including in the field of nano science. The seventeenth company—**Cameron International**, which is in the energy sector, only noted that it funded university research along with research at a private spin-off business, NanoMech. IBM and Intel are the only companies to reference nano in their business descriptions that also are included in the Nanotechnology Consumer Products Inventory (*see below*).

Financial discussions: Thirteen companies included a reference to nano in *Management's Discussion and Analysis (MD&A) of Financial Condition and Results of Operations* (Item 7 in Form 10-Ks), and a fourteenth company did so in a note to its consolidated financial statements. Nine of the thirteen companies are in the information technology sector, including all six that reported risk factors related to nanotechnology *(see above)*. The additional three are **Intel, KLA-Tencor** and **Qualcomm**. Seven of the nine are in the semiconductor & semiconductor equipment industry, while Qualcomm is in the communications equipment industry and Sandisk is in the computers and peripherals industry. The four additional companies referencing nano in their MD&A included two in the health care sector—**Abbott Laboratories** and **Becton Dickinson**; **Air Products & Chemicals** in the materials sector and **Newell Rubbermaid** in the consumer discretionary sector.

(See Appendix A for more details on nano references in Form 10-Ks among S&P 500 companies, p. 55.)

Corporate Responsibility and Sustainability Reviews

An even smaller number of S&P 500 companies, 22, discussed their involvement in nanotechnology as part of their corporate responsibility or sustainability reporting. (Si2 reviewed corporate responsibility and sustainability reports or the sections of corporate websites devoted to these issues in the fourth quarter of 2013.)

Disclosure: Four companies—all in the consumer staples sector—focused on disclosing whether they were using nanotechnology, and six others used these communications to state their support for nanotechnology development**.** Notably, shareholders have been in contact on this issue with six companies (including a predecessor company) of the 10. *(See the Section on Shareholder Engagement for more details.)*

Mondelez International, one of the world's largest snack companies, and **Colgate-Palmolive**, a leading consumer products company, reported that they do not use nanotechnology. Mondelez commented, however, that "as a leading food company, we need to understand the potential this technology may hold for us in terms of food safety, product quality, nutrition and sustainability. That is why our research and development teams always keep their eyes on the scientific research, as well as consider potential applications where nanotechnology may be used in packaging material." **Estee Lauder** amended a previous statement that it did not formulate using nano particles. Noting that it had defined nano particles as ingredients intentionally processed to be nano sized, the company reported that it has since "identified a small number of products that do contain a limited number of these nano sized ingredients." Estee Lauder added that "the definition of 'nano' terms as they relate to cosmetics ingredients continues to evolve in accordance with emerging scientific study. In the future, reference to 'nano' may capture more than ingredients which are intentionally manufactured to be nano sized." **Avon** noted that it "uses a limited number of ingredients characterized as nanomaterials," primarily titanium dioxide or zinc oxide, and that it uses them in a wide range of cosmetic products to provide protection against the ultraviolet rays of the sun.

Merck clearly stated that it "supports the use of nanotechnology to develop innovative drugs, vaccines and consumer products that address the unmet medical and wellness needs of people and animals," while **Johnson & Johnson** reported to its stakeholders that nanoparticles "offer the potential to develop improved medicines, medical devices and personal care products, such as sunscreens." **E.I. DuPont de Nemours** stated that "Our perspective is that new technologies—such as biotechnology and nanotechnology—offer compelling benefits, and should be part of the suite of solutions that help bring safe and nutritious food to the world, decrease our dependence on fossil fuels, and safeguard people and the planet." **Hewlett Packard** similarly touted the benefits of nanotechnology, stating that "Nanotechnology holds long-term promise for creating electronics applications that require fewer materials and consume less energy." **IBM** also pointed out that nanotechnology "can make products lighter, stronger, cleaner, less expensive and more precise, and has been critical to advancements in the IT industry," and **Lockheed** said, "Nanotechnology can offer significant sustainability benefits by reducing materials use."

Risk assessment and/or management: Ten companies, including seven of the 10 just mentioned, discussed risk assessment and/or risk management related to nano products or nanotechnology. In contrast to risk reporting in the Form 10-Ks by the six IT companies that focused on production challenges, the companies that focused on risks related to health and safety issues in their corporate responsibility or sustainability communications are more diverse. **Avon Products** stated that the "safety of each of the ingredients characterized as a nanomaterial currently used by Avon has been individually and fully evaluated by our scientists," and discussed safety and regulatory issues in more detail. **Merck** discussed health and safety measures related to patients, employees and the environment. **Estee Lauder** emphasized that it is paying close attention to the dialogue on nano and will evaluate its use of nanoparticles consistent with "prevailing scientific opinion." **Mondelez** said that "If we ever intend to use nanotechnology, we will make sure that the appropriate environmental, health and safety concerns have been addressed." **Johnson & Johnson** said that it researches the environmental impact of nano-sized particles, investigates product safety and develops advanced protective methods for workers. The company also reported that its *Guideline for the Responsible Use of Nanotechnology* sets standards for responsible behaviors across the corporation and also provides a general framework to influence the wider global community in developing nanotechnology in a responsible manner.

Ford reported it is "working to understand the health and safety issues that may be posed by nanomaterials" and that it has joined with other automakers to sponsor research into nanomaterials' potential impact on human health and the environment. **Goodyear Tire & Rubber** noted it is a leader in an industry group that is working with the Organisation for Economic Co-operation and Development to "examine sustainable development and use of nanomaterials by the tire industry."

IBM noted that it was one of the first companies to create safe work practices and health and safety training for employees working with nanoparticles, and noted its work with industry and university-based research programs on environmental, health and safety impacts of nanotechnology. **Hewlett Packard** discussed a nanomaterial risk assessment tool that it developed in 2012 to help assess and manage health and safety risks associated with the use of nanomaterials. The company added that the tool, among other things, accounts for "potential incomplete information on health hazards and exposure scenarios." Lastly, in a discussion of sustainable manufacturing, **Texas Instruments** reported on its work with manufacturing and research groups to "better understand and mitigate the risks associated with using nanomaterials."

Products: Some 13 companies highlighted specific products containing nanomaterials or developed with nanotechnology. Only four of these 13 companies also made a reference to nano in their business descriptions in their Form 10-Ks, and three of the four made distinct references in their corporate responsibility or sustainability communications. While **Dow Chemical** noted a nanofiltration element in its Form 10-K, it reported receiving financial assistance from the European Commission for a "nanotechnology-based high performance insulation foam system for energy efficiency in buildings" in its *Annual Sustainability Report*. Whereas **IBM** made a broad reference to nano in its Form 10-K, it discussed several of its achievements in nanotechnology in its *Corporate Responsibility Report*, including logic circuits that use carbon nanotubes and hard disk drive recording heads that incorporate subnanometer material layers. **Jacobs Engineering** discussed a nanofiltration-based process for the chlor-alkali industry, which produces chlorine and caustic soda, in its *Sustainability Report,* while it noted advanced technology clients in the nano science field requiring specialized buildings in its Form 10-K. **Intel** discussed its processors, transistor technology and flash memory products in both reports.

These 13 companies included four in the health care sector—**Celgene, Johnson & Johnson, Merck** and **Thermo Fisher Scientific**. **Celgene,** for instance, noted that a principal therapy in its oncology division uses a "unique nanotechnology-based formulation process," and **Merc**k provided three examples of how it is using nanotechnology, including in Coppertone sunscreen products.

In addition to making a broad statement in support of nanotechnology, **Hewlett Packard** specifically noted that outcomes of its research in nanoarchitecture, nanoelectronics, nanomechanics and nanophotonics include advances in memristor-based computer memory. **Ford** discussed using nano-based materials to reduce vehicle weight while increasing strength, as well as using antimicrobial nanosilver coatings in vehicle interiors. **Lockheed Martin** reported that it was using carbon nanomaterials to "build stronger, lighter and higher-performing structures with additional electrical and mechanical properties for use on the F-35 aircraft and the Juno spacecraft." **Cummins** discussed its advanced nanotechnology based media, NanoNet™, for fuel filtration. **Air Products & Chemicals** highlighted its acquisition of DuPont's interest in DuPont Air Products NanoMaterials LLC, thereby "strengthening our position in the high-growth global semiconductor and wafer polishing markets."

(See Appendix B for details on nano references in corporate responsibility and sustainability communications among S&P 500 companies, p. 76.)

Nanotechnology Consumer Products Inventory

The Project on Emerging Nanotechnologies (PEN) of the Woodrow Wilson International Center for Scholars' Science & Technology Innovation Program (STIP) oversees a Consumer Products Inventory (CPI) that attempts to track nanotechnology consumer products and their manufacturers. PEN acknowledges that "while not comprehensive, this inventory gives the public the best available look at the 1,600+ manufacturer-identified nanotechnology-based consumer products introduced to the market."[3] PEN reports that U.S. companies account for more than 740 products (nearly half of the total) as of October 2013. PEN uses a variety of sources to compile its inventory and includes categories indicating the level of confidence in the nano claims.

As of late 2013, PEN's inventory included at least 18 S&P 500 companies. However, only four of these companies discussed nanotechnology in their Form 10-Ks or corporate responsibility or sustainability reporting, and only two of these—Intel and IBM—reported producing nano products. PEN listed **Intel** and **IBM** along with two additional companies in the information technology sector—**Apple** and **Motorola Solutions**—as using nanotechnology for miniaturization. Two companies in the consumer discretionary sector that sell clothing or bedding also were included: **Gap** for using carbon nanotubes in its Nano-Care® Stressfree Khakis and **J.C. Penney** for its Nano-Tex® Sheet Set. Other listed uses included sun protection for plastics by **DuPont**, hardness and strength in automotive exteriors by **General Motors**, nano-nylon material in plastic bottles by **Honeywell**, a catalyst for batteries by **Stanley Black & Decker** and environmental treatment for a gas cookstove by **Whirlpool**. Of these 11 companies, eight made claims about or advertised the use of nanotechnology in their products or included "nano" in the product name. **DuPont** was not the source of information for its products, and information on the source of the nanotechnology claim was not available for **Honeywell** or **Whirlpool**.

The inclusion of another seven S&P 500 companies in the inventory was tied to their use of titanium dioxide, which is used as a color brightener or anti-caking agent, and illustrates the difficulty and resulting controversy over identifying nano products. Debate over the extent of nano-sized particles among food grade titanium dioxide particles prompted the 2014 shareholder resolution to Dunkin' Donuts, a recent Friends of the Earth report,[4] subsequent coverage in Mother Jones Magazine[5] and the removal of six of these companies from the inventory pending a review of their source. All six companies—**Coca-Cola, General Mills, Hershey's, J.M. Smucker, Kellogg** and **Kraft Foods**—are in the food or beverage industries and among 96 food products listed in the inventory, including 89 based on a peer-reviewed paper published in the journal *Environmental Science and Technology*.[6] The research paper found that 36 percent of the particles in a food-grade titanium dioxide sample were less than 100 nm in at least one dimension. The researchers then measured the concentration of titanium dioxide in these companies' products. They assumed the presence of nano-sized particles based on the sample but did not test all

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[3]PEN was established in 2005 to help ensure that as nanotechnologies advance, possible risks are minimized, public and consumer engagement remains strong, and the potential benefits of these new technologies are realized. The Pew Charitable Trusts initially funded the project, which continues to be funded through STIP. For more information on CPI, see http://www.nanotechproject.org/cpi/

[4]Friends of the Earth. (May 2014). Tiny Ingredients, Big Risks: Nanomaterials Rapidly Entering Food and Farming. Retrieved from http://libcloud.s3.amazonaws.com/93/25/c/4723/2014_Tiny_Ingredients_Big_Risks_Web.pdf

[5]Philpott, T. Mother Jones. (May 28, 2014.) Is Big Dairy Putting Microscopic Pieces of Metal in Your Food? Retrieved from http://www.motherjones.com/tom-philpott/2014/05/nanotech-food-safety-fda-nano-material.

[6]Weir, A.,Westerhoff, P., Fabricius, L. and von Goetz, N. (January 18, 2012.) Titanium Dioxide Nanoparticles in Food and Personal Care Products. Retrieved from http://pubs.acs.org/doi/abs/10.1021/es204168d

products specifically for nano-sized particles. Adding to the confusion is that the European Union's definition of nanomaterial requires 50 percent or more of a material's particles to be nano-sized. Separately, the inventory listed **Colgate-Palmolive** as using titanium dioxide in its Colgate and Ultrabrite toothpastes, although the company reported in its *2012 Sustainability Report* that it does not use nanotechnology in its products.

(See Appendix C for a listing of these S&P 500 companies and their products, p. 87.)

Products and Processes

Roughly 30 years ago, scientists developed tools that allowed them to see, measure and identify nanoscale materials. In the late 1990s, companies began selling products made with nanotechnology. *(See Box 1 for a Nanotechnology Timeline in the United States, p. 22.)* Today's consumer products market includes a wide range of products containing nanomaterials, including makeup, sunscreen, food storage products, appliances, clothing, electronics, computers, sporting goods and coatings.[7] As noted earlier, many nanomaterials and processes have been used to improve existing products. The products include:

> lightweight nanotechnology-enabled automobile bumpers that resist denting and scratching, golf balls that fly straighter, tennis rackets that are stiffer (therefore, the ball rebounds faster), baseball bats with better flex and "kick," nano-silver antibacterial socks, clear sunscreens, wrinkle- and stain-resistant clothing, deep-penetrating therapeutic cosmetics, scratch-resistant glass coatings, faster-recharging batteries for cordless electric tools, and improved displays for televisions, cell phones, and digital cameras.[8]

Almost all high-performance electronic devices manufactured in the past decade use some nanomaterials. In addition, several nanomaterials, including nanosilver, nanotitania and carbon nanotubes, can be found in many different types of products, including sports equipment, paints, flooring, clothing and children's products, according to a November 2013 U.S. Consumer Product Safety Commission report.[9]

Altogether, the Nanotechnology Consumer Products Inventory reports that companies have introduced more than 1,600 such products into the marketplace between 2005 and October 2013.[10] The inventory has seen a 24 percent increase in products since its last update in 2010. PEN notes that this figure is likely a very low estimate of the actual number of products currently on the market that use nanotechnology, since there likely are hundreds of more products that have not been identified as using nanotechnology by their manufacturers. PEN also notes that this number reflects only consumer products and does not take into account the many commercial and industrial uses of nanotechnology and nanomaterials that can currently be found on the market.

[7] National Institute for Occupational Safety and Health. (November 2013). Current Strategies for Engineering Controls in Nanomaterial Production and Downstream Handling Processes. Retrieved from http://www.cdc.gov/niosh/docs/2014-102/

[8] National Nanotechnology Initiative. (n.d.) Nanotechnology Timeline. Retrieved from http://www.nano.gov/timeline

[9] U.S. Consumer Product Safety Commission. (November 20, 2013). Fiscal Year 2014 Operating Plan. Retrieved from http://www.cpsc.gov//Global/About-CPSC/Budget-and-Performance/FY2014OperatingPlan.pdf

[10] Project on Emerging Nanotechnologies. (October 2013). Analysis. Retrieved from http://www.nanotechproject.org/cpi/about/analysis/

Box 1
Nanotechnology Timeline in the United States

Early 1980s	Tools to image and measure extended into the nanoscale.
Early 1990s	Basic and applied nanoscience research began in earnest; early nanotechnology companies began to operate.
Late 1990s/ Early 2000s	Consumer products using nanotechnology began appearing in the marketplace.
Early 2000s	Focused government R&D began under the National Nanotechnology Initiative (NNI), which involves the nanotechnology-related activities of 20 departments and independent agencies. The government launched the NNI in 2000, and Congress passed the 21st Century Nanotechnology Research and Development Act in 2003 to provide a legislative foundation for the initiative. The Obama Administration considers the NNI to be one of its top science and technology priorities.
2004	Public debate over nanotechnology began to gain traction.
2014	More than 1,600 nanotechnology-based consumer products are on the market.

The Nanotechnology Consumer Products Inventory's largest main category is health and fitness, with nearly 800 products, and includes cosmetics and sunscreens. PEN also reports on levels of disclosure; it found that only a small set of nanomaterials is explicitly referenced in consumer products. The most common material mentioned in product descriptions is silver (383 products). Titanium (179, including titanium dioxide) has surpassed carbon (87 including fullerenes) since the 2010 update, followed by silica (52), zinc (36, including zinc oxide) and gold (19).

Future Uses

While industries producing the consumer products noted above predominate in the nano field, the industries with the greatest potential for nanotechnology to impact future products and services include healthcare, IT and energy systems. These industries are predicted to benefit from active nano substances that react to the environment and results in nanostructures, such as targeted drugs and 3D transistors, or nanosystems, which include guided assembling and robotics.[11] Opportunities for nanotechnology in medicine and agriculture are great given that a majority of biological processes also occur at the nanoscale. Active nano systems are expected to enhance disease detection, deliver drugs to targeted cells or enhance imaging for medical diagnostics. A study published in the January 2013 issue of the *Nanomedicine: Nanotechnology, Biology, and Medicine Journal* found that nearly 250 nanomedicine prod-

[11] Roco, M. (March 28, 2012). Nanotechnology Research Directions for Societal Needs in 2020. [Powerpoint presentation]. Retrieved from http://nano.gov/sites/default/files/roco.pdf

ucts are approved for use or are in various phases of clinical study in humans. For the purposes of the study, the authors defined nanomedicine as the use of nanoscale or nanostructured materials in medicine, engineered to have unique medical effects based on their structures, including structures with at least one characteristic dimension up to 300 nanometers (nm).[12] Developing nanotechnology in health care can be quite time consuming, as companies navigate lengthy and costly regulatory approval processes.

Companies face many additional technological and market risks in bringing nano products or processes to market. Examples include:

- the challenge of replicating nanomaterials at large volumes;
- sorting through overlapping intellectual property rights;
- potential financial liabilities associated with safety, regulatory and societal factors;
- convincing suppliers to change or adapt their manufacturing processes to make use of nanomaterials or take on other added costs and risks associated with nanomaterials; and
- adaptation by intermediate suppliers, given that researchers and developers of nanomaterials typically are separated from the end-users of the technology by several value chain steps, particularly in the case of process innovations.[13]

U.S. Emphasis

The U.S. government is concentrating on five areas "ripe for significant advances through close and targeted program-level interagency collaboration," known as Nanotechnology Signature Initiatives (NSIs).[14] Notably, these are areas where agencies can work together to accelerate nanotechnology development in support of national priorities and innovation strategy; they are not necessarily the top nano drivers worldwide. The five NSIs focus on:

- Solar
- Nanomanufacturing
- Nanoelectronics
- Knowledge infrastructure and
- Sensors

Investments and Markets

Industry estimates aired at a European forum in 2011 put cumulative investments in global nanotechnology at more than $67 billion from 2007 through 2010. Annual global funding was estimated at $17.8 billion in 2010, with corporate spending providing half and overtaking government funding for the first

[12] Etheridge, M., Campbell, S., Erdman, A., Haynes, C., Wolf, S. and McCullough, J. (May 23, 2012). The big picture on nanomedicine: the state of investigational and approved nanomedicine products. *Nanomedicine: NBM 2013;9:1-14.* Retrieved from http://download.journals.elsevierhealth.com/pdfs/journals/1549-9634/PIIS1549963412002882.pdf

[13] Crawley, T., Koponen, P., Tolvas, L. and Marttila, T. (March 16, 2012.) Background Paper 2: Finance and Investor Models in Nanotechnology. Retrieved from http://www.oecd.org/sti/nano/49932116.pdf

[14] National Nanotechnology Initiative. (n.d.). Nanotechnology Signature Initiatives. Retrieved from http://nano.gov/signatureinitiatives

time. Governments provided an estimated 46 percent of total funding in 2010 and venture capital 4 percent. Venture capital investments fell by 40 percent between 2008 and 2009, and by another 21 percent from 2009 to 2010.[15]

Obtaining accurate data on investment in nanotechnology in the commercial sector is challenging, and no comprehensive data on nanotechnology in products and applications exists. Few current products are 100 percent nanotechnology, making it difficult to estimate what portion of a product's development or manufacturing costs should be counted as such. Similar challenges face investment projects, as well as R&D funding. Other challenges are the limited requirements to label products that contain nanomaterials or have been developed using nanotechnology. As a result, much remains unknown about the scale and scope of nanotechnology in the marketplace. Undercounting can occur because some companies do not advertise or label their products as containing nanomaterials.

Looking to the future, one of the greatest challenges for estimating investments in nanotechnology will be a trend of a growing number of companies away from labeling or identifying nanotechnology. Product description and marketing increasingly are focusing on the product's characteristics and benefits, not on the underlying nanotechnology or nanomaterials that make it possible. A green energy company is likely to promote the next generation battery made possible by nanotechnology without ever using the word "nano," for instance.

Data on government funding is more readily available. More than 60 nations fund nanotechnology programs. The United States is the world leader in nanotechnology, measured by R&D investment, cited publications and patents.[16] Other OECD countries, including Germany, France, Japan and Korea, as well as China also are very active.

Future markets: Wide variations exist in market forecasts for nanotechnology over the next 10 to 20 years. Early estimates, and many current estimates, are in the trillions of dollars, while other current estimates have scaled back expectations to the billions. This is still a large figure. An often cited 2010 panel report by the World Technology Evaluations Center estimated a $3 trillion market by 2020,[17] and in 2013 the National Research Council reported the global market for nanotechnology is expected to

[15]Raje, J. (May 30, 2011). Commercialisation of Nanotechnology: Global Overview and European Position. [Powerpoint presentation]. Retrieved from http://www.euronanoforum2011.eu/wp-content/uploads/2011/09/enf2011_support-commercialisation_raje_fin.pdf

[16]Youtie, J. and Shapira, P. (Feb. 19, 2013). Time to Reassess the Promise of Nanotechnology?: An Analysis of Research, Developments and Commercialization. [Video]. Retrieved from http://vimeo.com/60019397

[17]Roco, M., Mirkin, C. and Hersam, M. (September 30, 2010). Nanotechnology Research Directions for Societal Directions in 2020, Retrieved from http://www.wtec.org/Nano_Research_Directions_to_2020.pdf

exceed $3 trillion by 2015.[18] The European Commission reports that products underpinned by nanotechnology are forecast to grow from a global volume of €200 billion in 2009 to €2 trillion by 2015.[19]

Market projections face challenges similar to investment estimates with regard to accuracy, but there are indications that while nanotechnology markets are undisputedly growing, some applications are taking longer to commercialize than originally envisioned and other markets were simply overestimated. Organic photovoltaics is one such example. In 2010, some forecasts were predicting sales of $6 billion to $7 billion in sales. In 2011, these fell to below half a billion. Reasons include improvements in incumbent products, such as silicon; life-cycle assessments taking on greater importance; and recognition that developing nanomaterials and applications can require considerable energy.[20]

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[18] National Academies Press. (September 12, 2013). Report Finds Mixed Progress on Advancing a Research Agenda for Environmental, Health, and Safety Aspects of Nanomaterials; Oversight by Single Agency Could Overcome Barriers to Implementation. Retrieved from http://www8.nationalacademies.org/onpinews/newsitem.aspx?RecordID=18475

[19] Policy Issues. European Commission. (n.d.) Retrieved from http://ec.europa.eu/research/industrial_technologies/policy_en.html

[20] Youtie, J. and Shapira, P. (Feb. 19, 2013). Time to Reassess the Promise of Nanotechnology?: An Analysis of Research, Developments and Commercialization. [Video]. Retrieved from http://vimeo.com/60019397

Environmental, Health & Safety

The growth of commercial applications of nanomaterials has been rapid and includes both new uses of existing nanomaterials and the introduction of altogether new materials. Nanomaterials can be used in a nearly infinite variety of combinations of commercial products and processes. Nanomaterials can be difficult to control. If nanoparticles come into contact with one another, they can fuse and change their shape and properties. Chemistry, biology, electronics, physics, materials science and engineering all converge on the nanoscale, with potentially unexpected combinations.[21] Nanomaterials produced by researchers in a lab may not end up being used as originally intended (if a specific use was ever intended) as they move up the value chain. This rapid pace of development, combined with the complex nature and broad scope of nanotechnology, makes it difficult for regulators to keep abreast of new applications and understand their implications for human health and ecosystems.

A recent review by the National Research Council (NRC) concluded that "Environmental, health, and safety research efforts are not keeping pace with the increasing and evolving applications of nanotechnology, and the potential effects of these materials on humans and ecosystems are still not fully understood."[22] *(See Box 2 for the NRC's EHS Research Recommendations and Review, p. 27.)* Particularly vexing for nanotechnology assessments is that EHS implications can be application-specific. Scientists are attempting to develop predictive models on how nanomaterials will act in their environment throughout their life cycle to enable regulation in a timely fashion, but they are finding that the health and environmental impacts can be dependent on how the nanomaterial will be used and with what it may interact. The ideal is to identify application-specific risks, taking into account the effects of nanomaterials in the particular biological and mechanical context of each application. But do governments have the resources to conduct such specific research? And how well can regulators anticipate and take into account new uses of nanomaterials that might alter their effects?

Nearly all recognize that marketplace acceptance for products created with nanomaterials or by nano processes hinges on consumers believing their benefits outweigh the risks for humans and the environment. Calls are increasing for supporters of nanotechnology to more clearly communicate both the benefits and risks of nanotechnology so as to secure and maintain public acceptance over the long term. Many point to the ongoing health and safety debate over GMO (genetically modified organisms) products as a debate those involved in the nano field would like to avoid. Still others point to nuclear power as an example of risks being downplayed as the technology was commercialized, only to experience a significant public backlash following accidents.

[21] Allianz AG. (2005). Small Sizes that Matter: Opportunities and Risks of Nanotechnologies. Retrieved from http://www.oecd.org/science/nanosafety/44108334.pdf

[22] National Academies Press. (September 12, 2013). Report Finds Mixed Progress on Advancing a Research Agenda for Environmental, Health, and Safety Aspects of Nanomaterials; Oversight by Single Agency Could Overcome Barriers to Implementation. Retrieved from http://www8.nationalacademies.org/onpinews/newsitem.aspx?RecordID=18475

Box 2
National Research Council's EHS Research Recommendations and Review

Concerned that the U.S. government's environmental, health and safety research efforts were not keeping pace with the increasing and evolving applications of nanotechnology, in 2012 the National Research Council (NRC) recommended four high-priority research areas:

1. quantifying and characterizing the origins of nanomaterial releases;
2. understanding processes that affect exposure and hazard;
3. nanomaterial interactions in complex systems ranging from subcellular to ecosystems; and
4. an adaptive research and knowledge infrastructure for accelerating progress and providing rapid feedback to advance research.[1]

In 2013 the NRC reviewed progress in its recommended research areas and found that "little work has been done in implementing an integrated research strategy throughout the federal government"[2] and "uncertainty about the implications of potential exposures of consumers, workers, and ecosystems to these materials persists."[3] After creating a set of indicators for each research area, the NRC identified only one that met the goal of "expected sustained progress." The NRC also maintained that the National Nanotechnology Initiative would "benefit from a clearer separation of authority and accountability for its environmental, health, and safety research enterprise in relation to its mandate to promote nanotechnology development and commercialization."[4]

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[1]National Research Council. (2012) *A Research Strategy for Environmental, Health, and Safety Aspects of Engineered Nanomaterials*. Retrieved from http://www.nap.edu/catalog.php?record_id=13347
[2]National Academies Press. (September 12, 2013). Report Finds Mixed Progress on Advancing a Research Agenda for Environmental, Health, and Safety Aspects of Nanomaterials; Oversight by Single Agency Could Overcome Barriers to Implementation. Retrieved from http://www8.nationalacademies.org/onpinews/newsitem.aspx?RecordID=18475
[3]National Research Council. (2013). *Research Progress on Environmental, Health, and Safety Aspects of Engineered Nanomaterials.* Retrieved from http://www.nap.edu/catalog.php?record_id=18475
[4]National Academies Press. (September 12, 2013). Report Finds Mixed Progress on Advancing a Research Agenda for Environmental, Health, and Safety Aspects of Nanomaterials; Oversight by Single Agency Could Overcome Barriers to Implementation. Retrieved from http://www8.nationalacademies.org/onpinews/newsitem.aspx?RecordID=18475

Health & Environmental Concerns

The unique properties and behaviors of some nanomaterials—their small size, increased reactivity and durability—lead to uncertainties regarding how they interact with biologic systems, ecosystems and other nanomaterials.

Nanomaterials can gain access to the human body following inhalation or ingestion, and possibly also via skin penetration, especially if the skin is damaged. If inhaled, nanomaterials may not only affect the lungs but also enter the bloodstream and gain access to tissues and organs throughout the body. Their small size facilitates penetration through cell membranes. Some nanomaterials can cross the blood/brain barrier, which protects the brain from harmful chemicals in the blood. While purposely crossing this barrier to treat a brain tumor would be a tremendous benefit, inadvertent penetration is a concern. Nanomaterials also could potentially accumulate in organs. Nanoparticle interaction with cell structures such as ribosomes and DNA also may have health implications. Human toxicity is still being studied and it is unknown which nanoparticles are more toxic than their macro-scale forms.

A November 2013 report by the National Institute for Occupational Safety and Health (NIOSH) characterized initial findings from toxicological studies on nanomaterials and animals conducted by scientists around the world as "concerning." [23] (NIOSH is part of the Centers for Disease Control and Prevention (CDC) and is the lead federal agency conducting research and providing guidance on the occupational safety and health implications and applications of nanotechnology.) Examples include a study linking some carbon nanotubes to asbestos-like pathology in mice.[24] NIOSH also cited studies showing that nanoparticles can translocate to the circulatory system and to the brain, causing oxidative stress,[25] which is associated with age-related diseases and thought to be involved in the development of cancer. The Congressional Research Service has noted similar studies and also points to research indicating the heightened reactivity of some nanoparticles potentially can result in cell damage in animals.[26]

Researchers are developing use scenarios and decision trees for regulators to focus on highest risk applications, with lifecyle analysis playing a key role. Nanomaterials encased in resins, if they remain bound to a product throughout their lifecycle and are disposed of properly, likely pose less risk than dispersive applications, such as aerosol sprays. In between would be paints or coatings, which initially would pose little risk but could degrade. With increased knowledge, companies can embrace the "safer by design" concept and avoid many potential product risks. In the meantime, environmental groups are paying special attention to nanoparticles in cosmetics and food, as well as products that may shed nanomaterials over time. The potential effects of sunscreen have gained considerable publicity of late and illustrate the differing views on exposure, as well as consumer reactions. *(See Box 4 on Nanomaterials in Sunscreen for more, p. 30.)* Nanosilver in antibacterial bedding or clothing also has been gaining consumer attention. *(See Box 3 on Nanosilver, p. 29.)*

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[23]National Institute for Occupational Safety and Health. (November 2013). Current Strategies for Engineering Controls in Nanomaterial Production and Downstream Handling Processes. Retrieved from http://www.cdc.gov/niosh/docs/2014-102/

[24]Poland, C., Duffin, R., Kinloch, I., Maynard, A., Wallace, W.A.H., Seaton, A, Stone, V., Brown, S., MacNee, W. and Donaldson, K. (2008). Carbon nanotubes introduced into the abdominal cavity of mice show asbestos-like pathogenicity in a pilot study. Retrieved from http://www.nature.com/nnano/journal/v3/n7/abs/nnano.2008.111.html

[25]Elder, A., Gelein, R., Silva, V., Feikert, T., Opanashuk, L., Carter, J., Potter, R., Maynard, A., Ito, Y., Finkelstein, J. and Oberdorster, G. ([2006). Translocation of inhaled ultrafine manganese oxide particles to the central nervous system. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/16882521. See also, Wang, .J, Liu, Y., Jiao, F., Lao, F., Li, W., Gu, Y., Li, Y., Ge, C., Zhou, G., Li, B., Zhao, Y., Chai, Z. and Chen, C. (2008). Time-dependent translocation and potential impairment on central nervous system by intranasally instilled TiO(2) nanoparticles. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/18929619

[26]Sargent, Jr., J. Congressional Research Service. (January 20, 2011). Nanotechnology and Environmental, Health, and Safety: Issues for Consideration. Retrieved from http://assets.opencrs.com/rpts/RL34614_20110120.pdf. See also Magrez, A., Kasas, S., Salicio, V., Pasquier, N., Seo, J.W., Celio, M., Catsicas, S., Schwaller, B., and Forro, L. (May 2006.) Cellular Toxicity of Carbon-Based Nanomaterials. Retrieved from http://pubs.acs.org/doi/abs/10.1021/nl060162e

Box 3
Nanosilver

Nanosilver's antibacterial properties have made it an attractive addition to a variety of consumer products, from socks to bedding to washing machines. Some, including the Natural Resources Defense Council (NRDC), are concerned that nanosilver's health effects are not well understood and that, unlike silver, nanosilver may penetrate organs and tissues in the body, such as the brain, lung, and testes.[1] Silver is known to bioaccumulate, and environmental groups have raised concerns that nanosilver could shed from clothing, bedding and washing machines, thereby creating runoff with nanomaterials that could be absorbed up the food chain.

In November 2013, the Ninth Circuit Court of Appeals agreed with the NRDC that the U.S. Environmental Protection Agency had improperly approved the use of nanosilver by a U.S. textile manufacturer. The court vacated the EPA's approval and sent it back to the agency for reevaluation. The court found that the EPA had data showing that nanosilver was at a level that should have triggered a finding of potential risk for toddlers exposed to nanosilver-treated textiles.[3] The EPA had conditionally registered HeiQ AGS-20—an antimicrobial pesticide product that contains nanosilver as a new active ingredient—for use in textiles under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) in December 2011.[4] A conditional use registration allows a product into commerce on the "condition" that the company will provide additional data to confirm the EPA's assessment that the product will not cause unreasonable adverse effects on human health or the environment. In this case, the EPA granted HeiQ Materials AG, a Swiss high-tech company, four years to provide the additional data.

Given the court ruling, many are watching what the EPA now will do with an application by Nanosilva LLC for another pesticide containing nanosilver—an antibacterial product intended for use in plastic products and textiles. The EPA had put out for public comment a proposal to conditionally register that pesticide in August 2013. Moreover, while the NRDC celebrated the court ruling, it notes that many other companies likely are using nanosilver without registering their products with the U.S. government. *(The section on Regulatory Oversight discusses EPA's requirements for nanomaterials in pesticides, pp. 46-48.)*

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[1]Sass, J. Natural Resources Defense Council. (November 19, 2013). Court Rules in NRDC's Favor to Limit Nanosilver in Clothing. Retrieved from http://switchboard.nrdc.org/blogs/jsass/court_rules_in_nrdcs_favor_to.html

[3]Sass, J. Natural Resources Defense Council. (November 19, 2013). Court Rules in NRDC's Favor to Limit Nanosilver in Clothing. Retrieved from http://switchboard.nrdc.org/blogs/jsass/court_rules_in_nrdcs_favor_to.html and Bergeson, L. (November 8, 2013). Court Vacates and Remands EPA's Conditional Registration of HeiQ's Nanosilver Products. Retrieved from http://nanotech.lawbc.com/2013/11/articles/united-states/federal/court-vacates-and-remands-epas-conditional-registration-of-heiqs-nanosilver-products/

[4]U.S. Environmental Protection Agency. (December 1, 2011). Pesticides News Story: EPA Announces Conditional Registration of Nanosilver Pesticide Product. Retrieved from http://www.epa.gov/oppfead1/cb/csb_page/updates/2011/nanosilver.html

Box 4
Nanomaterials in Sunscreens

Sunscreen manufacturers now commonly add nanoscale titanium dioxide and zinc oxide to their products. In addition to their sun-blocking properties, these materials also rub on clear instead of white and thick—an attribute consumers value and arguably makes them more likely to use sunscreen. Friends of the Earth (FoE) questions whether such nanomaterials may be able to penetrate cell membranes and prove toxic to cells and tissues, including damaging DNA. FoE also has voiced concerns that these nanomaterials may wash off of people while swimming or in the shower, potentially allowing them to be absorbed up the food chain and damage microbes that are helpful to ecosystems.

In 2006, FoE began advocating a moratorium on further commercial release of sunscreens, cosmetics and personal care products that contain engineered nanomaterials, as well as the withdrawal of such products currently on the market, until "adequate public, peer-reviewed safety studies have been completed, and adequate regulations have been put in place."[1] FoE is pushing the U.S. government and policymakers around the world to regulate nanotech industries with a precautionary approach "that puts people's health before corporate profits." FoE also is pushing for mandatory labeling of products that contain nanomaterials.[2]

U.S. and European regulators do not share these concerns. In 2012, the European Union approved nanoscale zinc for use in sunscreens (except in sprays and powders), saying it did not appear to pose a risk of adverse effects in humans after dermal application.[3] The U.S. Food and Drug Administration, which regulates sunscreen as a drug, says its tests also have not found risk.[4] Both **Merck**[5] and **Avon Products**[6] note in their corporate responsibility reports that current scientific data indicates that nanoscale zinc oxide or titanium dioxide are safe and used in their products.

To capitalize on concerned consumers, some companies have begun advertising their sunscreen products as "non-nano," although such claims are being questioned by environmental groups. The Environmental Working Group, an environmental health research and advocacy organization, reports that nearly all of these companies' sunscreens contain ingredients that would be considered nanomaterials under a broad definition of the term.[7] In March 2013, **Antaria**, a major supplier of zinc oxide, confirmed its sunscreen ingredients contained nanomaterials after strenuously denying it for months to the media, its customers and the Australian Stock Exchange. Prior to Antaria's admission, Friends of The Earth Australia had commissioned scientific tests on Antaria's products and lodged a complaint with the Australian Competition and Consumer Commission.[8] *(Continued on next page.)*

Environment—In addition to potential direct impacts on the human body, critics also are concerned about possible harm to ecosystems. Nanomaterials are highly reactive and may undergo transformation by environmental conditions such as temperature and salinity, biological conditions such as habitat, and the presence of co-contaminants.[27] They can adhere to surfaces and can move to water or soil, potentially leading to substantial exposure to ecosystems. Their small size also means nanoparticles have the potential to be transported large distances in air or water when released into the environment

[27]National Nanotechnology Initiative. (n.d.). Environmental, Health, and Safety Issues. Retrieved from http://www.nano.gov/you/environmental-health-safety

(Box 4, continued)

In 2008, nanoparticles of anatase titanium dioxide were found to cause premature weathering of the coating on pre-painted steel roof sheets after they had been handled by workers with sunscreen on their hands. Anatase titanium dioxide also has been shown to deteriorate other surface coatings and paints on cars and other consumer products. The finding raises concerns about its use on human skin.[9]

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[1]Friends of the Earth. (May 2006). Nanomaterials, Sunscreens, and Cosmetics: Small Ingredients, Big Risks. Retrieved from http://libcloud.s3.amazonaws.com/93/ce/0/633/Nanomaterials_sunscreens_and_cosmetics.pdf

[2]Friends of the Earth. (n.d.). Nanotechnology. Retrieved from http://www.foe.org/projects/food-and-technology/nanotechnology

[3]European Commission's Scientific Committee on Consumer Safety. (September 18, 2012). Opinion on Zinc Oxide (nano form) COLIPA S 76. Retrieved from http://ec.europa.eu/health/scientific_committees/consumer_safety/docs/sccs_o_103.pdf

[4]Thrasybule, L. National Public Radio. (June 14, 2011). FDA: Sunscreens Will Get More Scrutiny, New Labels. Retrieved from http://www.npr.org/blogs/health/2011/06/18/137175140/fda-sunscreens-will-get-more-scrutiny-new-labels

[5]Merck & Co. (July 23, 2013). Corporate Responsibility Report. Retrieved from http://www.merckresponsibility.com/focus-areas/environmental-sustainability/product-stewardship/nanotechnology/

[6]Avon Products. (2012). Corporate Responsibility Report. Retrieved from http://www.avoncompany.com/corporatecitizenship/corporateresponsibility/resourcecenter/policies_and_procedures/nanotechnology.html

[7]Environmental Working Group. (n.d.). Nanoparticles in Sunscreens. Retrieved from http://www.ewg.org/2013sunscreen/nanoparticles-in-sunscreen/

[8]Carbonell, R. ABC News. (March 4, 2013). Company's about-face on nano-free sunscreen claims. Retrieved from http://www.abc.net.au/news/2013-03-04/company27s-about-face-on-nano-free-sunscreen-claims/4551820

[9]Carbonell, R. ABC News. (March 5, 2013). Fresh concern over nano-particles hidden in sunscreen. Retrieved from http://www.abc.net.au/news/2013-03-05/fresh-concern-over-nano-particles-in-sunscreen/4552522

Some environmental groups, such as Friends of the Earth (FoE), also question claims of nanotechnology's environmental advantages when assessing the broad, overall view of nanotechnology's impact. Citing environmental advances that have failed to live up to expectations, large energy demands associated with nanomanufacturing and public funding of nano advances in the oil and gas industry, FoE concludes that "Nanotechnology may ultimately facilitate the next wave of expansion of the global economy, deepening our reliance on fossil fuels and existing hazardous chemicals, while introducing a new generation of hazards." [28] Critics also question whether some nano applications are solving one problem while creating another and point to environmental remediation as an example. Nanosilver can be used to filter water but questions remain about whether any accumulation in water bodies could be toxic to beneficial microbes or have adverse impacts on aquatic species.

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[28]Illuminato, I. and Miller, G., Friends of the Earth. (November 2010). Nanotechnology, climate and energy: Overheated promises and hot air? Retrieved from http://libcloud.s3.amazonaws.com/93/20/3/552/Nanotechnology-climate-and-energy-US.pdf

EHS concerns overblown: Others contend that concerns about nanotechnology EHS implications are often overgeneralized and overstated. A 2011 Congressional Research Service report summarized the following counterpoints:

- nanoscale materials are frequently embedded in other materials as part of the manufacturing process;
- some nanotechnology products, such as semiconductors, have nanoscale features but do not contain nanoscale particles;
- nanotechnology materials may replace other materials that have significant and known risks;
- some nanoscale particles tend to aggregate or agglomerate in the environment into larger particles that no longer have nanoscale dimensions; and
- people are regularly exposed to nanoscale particles produced naturally and as incidental by-products of human activities.[29]

EHS Research Gaining Momentum

EHS research related to nanotechnology originally was diffuse and not coordinated. By the end of the first decade of this century, however, it had become a field with authors citing one another. However, it is worth noting that in 2013, less than 7 percent of scientific papers on nanotechnology were referencing EHS issues, with most information in the bio realm.[30]

Governments have the ability to exert significant influence over research areas as they continue to fund nearly half of the world's nanotechnology research. While the U.S. government did not emphasize EHS from the outset of the National Nanotechnology Initiative (NNI) in 2000, EHS recently has become an important part of the NNI, as the timeline below shows:

- **2000:** The U.S. government launches the NNI. *(See Box 1 for more on the NNI, p. 22.)*
- **2003:** Congress passes the 21st Century Nanotechnology Research and Development Act. The Act mandates "integrating research on societal, ethical and environmental concerns with nanotechnology research and development."[31]
- **2006:** Work on an NNI Nanotechnology EHS Research Strategy begins.
- **2008:** The first official *NNI Strategy for Nanotechnology-Related Environmental, Health, and Safety (EHS) Research Report* is published.
- **2011:** The strategy document is updated.
- **2015:** Environment, Health & Safety becomes one of the NNI's five Program Component Areas defined for FY 2015.

The U.S. government also has significantly increased funding on the environmental, health and safety dimensions of nanotechnology, from $35 million in FY 2005 to an estimated $115 million requested for FY 2015. Cumulative U.S. government investments in nanotechnology-related environmental, health

[29] Sargent, Jr., J. Congressional Research Service. (January 20, 2011). Nanotechnology and Environmental, Health, and Safety: Issues for Consideration. Retrieved from http://assets.opencrs.com/rpts/RL34614_20110120.pdf

[30] Youtie, J. and Shapira, P. (Feb. 19, 2013). Time to Reassess the Promise of Nanotechnology?: An Analysis of Research, Developments and Commercialization. [Video]. Retrieved from http://vimeo.com/60019397

[31] U.S. Congress. (December 3, 2003). Public Law 108-153. Retrieved from http://www.gpo.gov/fdsys/pkg/PLAW-108publ153/html/PLAW-108publ153.htm

and safety research between FY 2005 and FY 2014 total around $900 million. While it has grown, this amount still remains small in comparison to overall U.S. government funding on nanotechnology. The cumulative NNI investment since fiscal year 2001, including the 2015 budget request of more than $1.5 billion, now totals almost $21 billion.[32] Accordingly, EHS funding represents around only 4 percent of the total amount the U.S. government has allocated to nanotechnology, although the percent has more than doubled, from under 3 percent in 2005 to more than 7 percent in the 2015 budget.

Consideration of the ethical, legal, and societal implications of nanotechnology also is part of the responsible development of nanotechnology, one of NNI's four goals, and could speed marketplace acceptance. Issues such as how nanotechnology research and applications are introduced into society; how transparent decisions are; how sensitive and responsive policies are to the needs and perceptions of the full range of stakeholders; and how ethical, legal, and social issues are addressed will determine public trust and the future of innovation driven by nanotechnology, says the NNI website.[33] Accordingly, the NNI has two centers that focus on these issues. The Center for Nanotechnology in Society at Arizona State University (CNS-ASU) is the largest center for research, education and outreach on the societal aspects of nanotechnology in the world. Its major partners are the Georgia Institute of Technology and the University of Wisconsin-Madison. The second U.S. Center for Nanotechnology in Society is at the University of California Santa Barbara.

National Nanotechnology Initiative Centers for Nanotechnology in Society

- Arizona State University, with partners Georgia Institute of Technology and University of Wisconsin-Madison
- University of California Santa Barbara

Collaborative efforts—Research also is underway globally at private companies, government labs, universities and NGOs. While international collaboration is not well suited to regulation given its economic consequences and countries' differing approaches, it is suited to research. Numerous international voluntary initiatives are:

- focusing on classifying industrial nanomaterials;
- reaching agreement on terminology;
- developing toxicity and exposure data;
- identifying avenues of interaction with the environment;
- standardizing the identification, measurement and reporting of data; and
- developing best practices for nanomaterial risk assessments and management.

Examples include the Organisation of Economic Co-operation and Development, which has two working groups on nanotechnology and is conducting research on nanomaterials' potential EH&S effects and regulatory needs, such as exposure measurement and exposure mitigation. The International Life Sciences Institute (ILSI) is sponsoring the NanoRelease Consumer Products project to measure release of nanomaterials from consumer products and the NanoCharacter project to create a framework and

[32]National Nanotechnology Initiative. (n.d.). NNI Budget. Retrieved from http://nano.gov/about-nni/what/funding
[33]National Nanotechnology Initiative, (n.d.). Ethical, Legal, and Societal Issues. Retrieved from http://nano.gov/you/ethical-legal-issues

roadmap to implement clear reporting of nanomaterial data across studies. (*See Box 5: Examples of Voluntary Codes, Frameworks & Collaborations Focused on Nanotechnology for more details and a sampling of additional efforts underway, below.)*

Box 5
Examples of Voluntary Codes, Frameworks & Collaborations Focused on Nanotechnology

Nano Risk Framework
(Environmental Defense Fund-DuPont collaboration)

http://www.nanoriskframework.com/

Collaboration began in 2005; framework published in 2007

Six-step lifecycle framework designed to establish a systematic and disciplined process for product developers to identify and reduce potential risks

Responsible Nano Code
(Code of Conduct for Responsible Nanotechnology)

http://www.nanotechia.org/activities/responsible-nano-code

Published in 2008

Led by the Royal Society, Insight Investment and the Nanotechnology Industries Association (NIA); later joined by the Nanotechnology Knowledge Transfer Network (an initiative sponsored by the U.K. government's Department of Trade and Industry)

Multiple NGO-business partners

Three levels:

- 7 Principles
- Examples of good practice
- Benchmarking framework

International Organization for Standardization (ISO)

The ISO established a technical committee (TC229) in 2005 to develop international standards for terminology and nomenclature, metrology and instrumentation, including:

- specifications for reference materials,
- test methodologies,
- modeling and simulation, and
- science-based health, safety and environmental practices.

As of December 2013, the technical committee had published 36 standards for 34 participating countries and another 13 observing countries.

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Organisation of Economic Co-operation and Development (OECD)
Working Party on Manufactured Nanomaterials (WPMN)

http://www.oecd.org/env/ehs/nanosafety/

Established in 2007

Its objective is to promote international cooperation in human health and environmental safety aspects of manufactured nanomaterials. In September 2013, the OECD announced a recommendation that its member countries adapt existing chemical regulatory frameworks to manage risks associated with manufactured nanomaterials.[1]

Phase I of its research focuses on evaluating a group of representative nanomaterials for potential EH&S effects; Phase II research will focus on regulatory needs, such as exposure measurement and exposure mitigation. To follow is its 2010 list of representative manufactured nanomaterials selected to support measurement and toxicology and risk assessments. These materials are now in, or are soon to enter into, commerce:

Fullerenes (C60)	Titanium dioxide	Silicon dioxide
Single-walled carbon nanotubes (SWCNTs)	Aluminum dioxide	Dendrimers
Multi-walled carbon nanotubes (MWCNTs)	Cerium oxide	Nanoclays
Silver nanoparticles	Zinc oxide	Gold nanoparticles
Iron nanoparticles		

Working Party on Nanotechnology (WPN)

http://www.oecd.org/sti/nano/oecdworkingpartyonnanotechnologywpnvisionstatement.htm

Established in March 2007

Its objective is to advise on emerging policy-relevant issues in science, technology and innovation related to the responsible development and use of nanotechnology.

As You Sow
Sourcing Framework for Food and Food Packaging Products Containing Nanomaterials

http://www.asyousow.org/health_safety/nanoframework.shtml

Published in December 2011

Designed to help food companies make informed decisions regarding sourcing products containing nanomaterials. The framework presents:

1. An introduction to key terms and issues
2. The current state of regulations and risks
3. Recommendations for companies on what to ask suppliers who offer food products and packaging that contain nanomaterials, and
4. Best practices from existing scientific, industry, and governmental frameworks.

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International Life Sciences Institute (ILSI)
Center for Risk Science Innovation and Application (RSIA)

http://www.ilsi.org/ResearchFoundation/RSIA/Pages/Nanotechnology.aspx

ILSI's NanoRelease Consumer Products project is a multi-stakeholder effort exploring methods for measuring release of nanomaterials from commercial products. Its NanoCharacter project aims to create a framework and roadmap to implement clear reporting of nanomaterial data across studies.

International Alliance for Nano EHS Harmonization

www.nanoehsalliance.org

The International Alliance for NanoEHS Harmonization is an interdisciplinary alliance of scientific experts, active in all aspects of this arena and drawn from Europe, Japan and the United States, that seeks to establish reproducible approaches for the study of nanoparticle hazard.

American Chemistry Council Nanotechnology Panel

http://nanotechnology.americanchemistry.com/Nanotechnology/About-Us

The panel advocates for responsible development of nanotechnology, sound approaches to nanotechnology policy and for research on potential health and environmental issues associated with nanotechnology. The panel participates in partnerships with universities, regulatory agencies and other experts to identify and communicate best practices. In September 2012, the Panel co-sponsored a workshop with the George Washington University on occupational exposure limits for engineered nanomaterials.

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[1] Organisation for Economic Co-operation and Development. (September 19, 2013). Recommendation of the Council on the Safety Testing and Assessment of Manufactured Nanomaterials. Retrieved from http://acts.oecd.org/Instruments/ShowInstrumentView.aspx?InstrumentID=298&InstrumentPID=314&Lang=en&Book=False

Regulatory Oversight

A sound regulatory regime would promote public acceptance of nanotechnology and create a hospitable environment for innovation. Regulatory standards typically are based on a rigorous testing and risk assessment process that requires a substantial body of data—a feature that likely will take years to create in the case of nanomaterials. In the meantime, regulators are making decisions based on the best information available. While governments may not see sufficient data to support standard setting, there is sufficient evidence to prompt government agencies to issue guidance regarding both worker exposure and agency reviews.

Many questions arise as to what constitutes an appropriate regulatory regime for nanotechnology. These include:

- Are material potential hazards associated with nanotechnology adequately identified and conveyed to and by regulatory agencies? To consumers? To the general public?
- Do regulators have the tools and instruments that will allow consistent and reliable tests and analyses?
- Do regulators have appropriate mechanisms to identify and oversee nano products before they enter the marketplace? Should they?
- Is new nano-specific regulation necessary to assure public health and safety? Or is current regulation sufficient?
- Regulations historically have defined materials by their chemical composition rather than by their size. Should regulations now focus on size, even if size does not consistently correlate to heightened hazard or risk? (To date, typically, the European Union has focused on size, while the United States has focused on molecular identity, properties and size).
- What research is needed to support responsible development of this technology?

Most countries are still grappling with how to answer these questions and, consequently, how to address nanotechnology. The European Union has instituted legislation with nano-specific provisions, placing it in a class by itself. The United States has limited itself to guidance rather than new mandatory regulation; and efforts to alter when a nanomaterial should be considered a "new" material that would trigger a government review have stalled out. Early U.S. federal agency efforts to mandate data collection on commercial applications also have not come to pass so far.

European Union

The European Union (EU) was the first to introduce nano-specific legislation. It now requires nano labeling for cosmetics and food products. The European Commission (EC), the EU's executive body, also was the first to define nanomaterials for legislative and policy purposes in October 2011. *(See Box 6 on Nanotechnology Definitions, pp. 38-40.)* The EU also appears to be introducing nano-specific provisions as pertinent directives come up for review. The wide-ranging Registration, Evaluation, Authorization and Restriction of Chemical Substances (REACH) regulation is currently under review, for instance, and while

Box 6
Nanotechnology Definitions

The definitions of "nanotechnology" and "nanomaterials" continue to be an area of controversy, with no universally accepted terminology. Varying definitions also are complicated since some bodies, such as the European Union, define nanomaterials for regulatory purposes while others, such as the United States, define nanomaterials more often for informational purposes. The following evolving definitions are used by the European Union, United States and the International Organization for Standardization.

European Union

Cosmetics Regulation (EU Regulation 1223/2009)

First piece of legislation to have nano-specific provisions, took effect in July 2013:

"'Nanomaterial' means an insoluble or biopersistant and intentionally manufactured material with one or more external dimensions, or an internal structure, on the scale from 1 to 100 nm."

http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:342:0059:0209:en:PDF

- Nanomaterials must be explicitly authorized. Products containing other nanomaterials not otherwise restricted by the Cosmetics Regulation will be the object of a full safety assessment at the EU level, if the Commission has concerns.
- Nanomaterials must be labeled in the list of ingredients with the word "nano" in brackets following the name of the substance, e.g. "titanium dioxide (nano)."
- Definition of nanomaterials differs from October 2011 definition.
- Interestingly, the labeling requirement has prompted some companies to include voluntary non-nano labeling on their products as a marketing tool for concerned consumers.

Commission Recommendation (2011/696/EU) on the definition of nanomaterial

"'Nanomaterial' means a natural, incidental or manufactured material containing particles, in an unbound state or as an aggregate or as an agglomerate and where, for 50% or more of the particles in the number size distribution, one or more external dimensions is in the size range 1 nm-100 nm."

The Commission adds, "the term 'nanomaterial' in Union legislation should be based solely on the size of the constituent particles of a material, without regard to hazard or risk. This definition, based only on the size of a material, covers natural, incidental or manufactured materials."
http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2011:275:0038:0040:EN:PDF

Food Information to Consumers Regulation (EU Regulation 1169/2011)

"'Engineered nanomaterial' means any intentionally produced material that has one or more dimensions of the order of 100 nm or less or that is composed of discrete functional parts, either internally or at the surface, many of which have one or more dimensions of the order of 100 nm or less, including structures, agglomerates or aggregates, which may have a size above the order of 100 nm but retain properties that are characteristic of the nanoscale.

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Properties that are characteristic of the nanoscale include:

(i) those related to the large specific surface area of the materials considered; and/or
(ii) specific physico-chemical properties that are different from those of the non-nanoform of the same material;"

http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2011:304:0018:0063:EN:PDF

- Beginning in December 2014, food products must clearly label engineered nanomaterials; ingredients in the form of engineered nanomaterials must be indicated in the list of ingredients and be followed by the word "nano" in brackets.

Replacement definition for engineered nanomaterial in EU Regulation 1169/2011 adopted in December 2013 (EU Regulation No 1363/2013)

"'Engineered nanomaterial' means any intentionally manufactured material, containing particles, in an unbound state or as an aggregate or as an agglomerate and where, for 50% or more of the particles in the number size distribution, one or more external dimensions is in the size range 1 nm to 100 nm."

- The change conforms to the EC's 2011 recommended definition (2011/696/EU discussed above) while taking into account that the regulation's original definition refers to "engineered" nanomaterials and not nanomaterials in general; natural and incidental nanomaterials are not be included in this definition.
- The change incorporates the International Organization for Standardization's definition (see below) for "engineered nanomaterial."
- Food additives included in prior European Union lists are not covered by this definition of "engineered nanomaterials." Recommends that the need for specific nano-related labelling requirements relating to those additives should be addressed as part of a general reevaluation of food additives that is underway.

http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2013:343:0026:0028:EN:PDF

International Organization for Standardization

A "nanomaterial" is a "material with any external dimension in the nanoscale or having internal structure or surface structure in the nanoscale."

An "engineered nanomaterial" is a "nanomaterial designed for a specific purpose or function.''

https://www.iso.org/obp/ui/#search

United States

National Nanotechnology Initiative's website definitions:

"Nanotechnology is the understanding and control of matter at the nanoscale, at dimensions between approximately 1 and 100 nanometers, where unique phenomena enable novel applications. Encompassing nanoscale science, engineering, and technology, nanotechnology involves imaging, measuring, modeling, and manipulating matter at this length scale."

http://www.nano.gov/nanotech-101/what

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"What is Nanotechnology?

Nanotechnology is science, engineering, and technology conducted at the nanoscale, which is about 1 to 100 nanometers."

http://www.nano.gov/nanotech-101/what/definition

Food and Drug Administration

Nanotechnology. A Report of the U.S. Food and Drug Administration Nanotechnology Task Force. **July 25, 2007** "The Task Force has not adopted a precise definition for 'nanoscale materials,' 'nanotechnology,' or related terms to define the scope of its work….Moreover, while one definition for 'nanotechnology,' 'nanoscale material,' or related term or concept may offer meaningful guidance in one context, that definition may be too narrow or broad to be of use in another. Accordingly, the Task Force does not recommend attempting to adopt formal, fixed definitions for such terms for regulatory purposes at this time. As FDA learns more about the interaction of nanoscale materials with biological systems and generalizable concepts that can inform the agency's judgment, it may be productive to develop formal, fixed definitions, appropriately tailored to the regulation of nanoscale materials in FDA-regulated products."

http://www.fda.gov/ScienceResearch/SpecialTopics/Nanotechnology/UCM2006659.htm#definitions

Guidance: Considering Whether an FDA-Regulated Product Involves the Application of Nanotechnology. **June 2014**

"At this time, when considering whether an FDA-regulated product involves the application of nanotechnology, FDA will ask:

1. Whether a material or end product is engineered to have at least one external dimension, or an internal or surface structure, in the nanoscale range (approximately 1 nm to 100 nm);
2. Whether a material or end product is engineered to exhibit properties or phenomena, including physical or chemical properties or biological effects, that are attributable to its dimension(s), even if these dimensions fall outside the nanoscale range, up to one micrometer (1,000 nm)."

http://www.fda.gov/RegulatoryInformation/Guidances/ucm257698.htm

Office of Pesticide Programs - Environmental Protection Agency

Nanoscale material: "An active or inert ingredient of a pesticide and any component parts thereof intentionally produced to have at least one dimension that measures between approximately 1 and 100 nanometers."

http://www.epa.gov/pesticides/regulating/nanotechnology.html

National Institute for Occupational Safety and Health (NIOSH)

"Engineered nanomaterials are materials that are intentionally produced and have at least one primary dimension less than 100 nanometers (nm)."

http://www.cdc.gov/niosh/docs/2014-102/

REACH currently contains no nano-specific provisions, amendments to REACH are expected to add nano-specific language. Given that the EU is the world's largest chemical market, the review of REACH has prompted some manufacturers to withhold products or delay development in case the EU institutes additional information requirements or product bans.[34] REACH is based around the "precautionary principle"—if there are risks of serious or irreversible damage to human health or the environment, this principle places the burden of proof on claims that no harm will be caused by an action or policy.

While the EU's definition of nanomaterials focuses on size, critics believe the definition is too narrow and that size may not be the best characteristic on which to base regulation. Measurement can be open to interpretation and be inconsistent, they say. Even engineered nanoparticles typically exist over a range of sizes and the EC's definition allows up to 49 percent of the total number of particles in a substance to be between 1 and 100 nm without the substance being considered a nanomaterial. The EC's definition is slated for review by December 2014.

Relevant EC laws about nanotechnology include a 2009 Cosmetics Regulation and in 2011 an EC recommendation on a definition and a food regulation. *(See Box 6, p. 38-40.)* Ongoing debate exists about whether REACH is sufficiently robust or whether modifications are necessary to address nanomaterials. REACH requires a company to update its assessments whenever the composition, use or knowledge of the risks of a chemical change. Concerns focus on whether volume thresholds are too low to require generation of enough pertinent data on nanomaterials. Nanomaterials and REACH are likely to be a topic of discussion for the next year or two.

In addition to regulations, in May 2011 the European Food Safety Authority (EFSA) published a guidance document for the risk assessment of engineered nanomaterial applications in food and feed. Touted as the first of its kind to give practical guidance for addressing potential risks arising from applications of nanoscience and nanotechnologies in the food and feed chain, the guidance covers risk assessments for food additives, enzymes, flavorings, food contact materials, novel foods, feed additives and pesticides.[35]

No other nations have adopted food or cosmetic legislation or measures similar to that of the European Union. Some individual European countries are working on registries, both voluntary and mandatory:

- **France:** France was the first European country to require companies, as well as private and public research laboratories, to identify use of nanoparticles on a website, www.R-nano.fr. Companies and laboratories must make a declaration if at least 100 grams (3.52 ounces) of a substance at the nanoscale was imported, produced or distributed in France. The rule took effect in January 2013 following a government decree in February 2012. Companies must make an annual declaration by May 1 regarding use in the prior year.[36]

[34] Bowman, D. (March 28, 2012). The Hare and the Tortoise: Nanotechnologies and the Race for Regulatory Certainty. [Video]. Retrieved from http://nano.gov/node/799

[35] European Food Safety Authority. (May 11, 2013). EFSA publishes first practical guidance for assessing nano applications in food & feed. Retrieved from http://www.efsa.europa.eu/en/press/news/sc110510.htm

[36] French Republic Ministry of Ecology, Sustainable Development, Transport and Housing. (February 17, 2012). Decree no. 2012-232 of 17 February 2012 on the annual declaration on substances at nanoscale in application of article R. 523-4 of the Environment code. Retrieved from https://www.r-nano.fr/?locale=en

- **Belgium:** Belgium implemented a reporting regime in February 2014. Registration for pure substances begins in 2016, while mixtures will have to be registered beginning in 2017. In 2017, the Belgian authorities will assess whether products containing nanomaterials must be registered. The Belgian Council of Ministers said it created the registry for health authorities in case a type of nanomaterials proved dangerous to the public health and for authorities responsible for the safety of workers.[37]

- **Denmark & Italy:** Denmark is considering a mandatory registry and Italy is considering a voluntary registry.[38]

United States

The Obama administration developed guidelines for U.S. agencies to follow in regulating nanomaterials in 2011. *(See Box 7 on Policy Principles for the United States, p.43.)* U.S. agencies also have issued guidelines but have not issued any mandatory regulations similar to the European Union's labeling requirements. Two federal agencies at the forefront of the nanotechnology debate in the United States are the Food and Drug Administration and the Environmental Protection Agency. Other U.S. regulatory agencies actively involved in nanotechnology and participating in the NNI include:

- the Consumer Product Safety Commission (CPSC),
- Occupational Health and Safety Administration (OSHA),
- Nuclear Regulatory Commission (NRC),
- Bureau of Industry and Security (BIS) of the Department of Commerce and
- the State Department's Directorate of Defense Trade Controls (DDTC).

Legislation that provides some legal basis for reviewing and regulating nanomaterials includes the Food, Drug and Cosmetic Act, Toxic Substances Control Act, Occupational Safety and Health Act and major environmental laws, such as the Clean Air and Clean Water Acts. Nanomaterials also present the potential for environmental impacts associated with waste disposal and site cleanup that would fall under the Resource Conservation and Recovery Act (RCRA), and the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) or "Superfund."[39] It is unlikely that Congress will pass any new legislation regulating commercial products in today's political environment.

Many are skeptical of the usefulness of these laws with regard to nanotechnology, particularly given funding levels of government agencies. Critics point out that agencies lack comprehensive mechanisms for identifying nanotechnology or nano-enabled products before they enter the marketplace. A

[37]Delafortrie, S. Residence Palace International Press Center. (February 7, 2014). Belgium set up a register of nanomaterials. Retrieved from http://www.presscenter.org/fr/pressrelease/20140208/la-belgique-met-en-place-un-registre-des-nanomateriaux

[38]Clancy, S., Evonik Industries. (June 11, 2013). International Challenges and Opportunities in Nanotechnology. [Powerpoint presentation]. Retrieved from http://www.nano.gov/sites/default/files/shaun_clancy_international_challenges_and_opportunities_in_nanotechnology_0.pdf

[39]Davies, J. C. Project on Emerging Nanotechnologies, Woodrow Wilson International Center for Scholars. (January 2006). Managing the Effects of Nanotechnology. Retrieved from http://www.nanotechproject.org/process/assets/files/2708/30_pen2_mngeffects.pdf

Box 7
Policy Principles for U.S. Decision-Making Concerning Regulation and Oversight of Nanotechnology and Nanomaterials Applications

In June 2011, the White House Office of Science and Technology developed a set of principles specific to the regulation and oversight of nanotechnology applications to guide the development and implementation of policies at the agency level. The principles reinforce an overarching approach for the regulation and oversight of emerging technologies released in March 2011.[1]

The nanotechnology principles state that "Specifically, to the extent permitted by law, Federal agencies will:

- To ensure scientific integrity, base their decisions on the best available scientific evidence, separating purely scientific judgments from judgments of policy to the extent feasible;
- Seek and develop adequate information with respect to the potential effects of nanomaterials on human health and the environment and take into account new knowledge when it becomes available;
- To the extent feasible and subject to valid constraints (involving, for example, national security and confidential business information), develop relevant information in an open and transparent manner, with ample opportunities for stakeholder involvement and public participation;
- Actively communicate information to the public regarding the potential benefits and risks associated with specific uses of nanomaterials;
- Base their decisions on an awareness of the potential benefits and the potential costs of such regulation and oversight, including recognition of the role of limited information and risk in decision making;
- To the extent practicable, provide sufficient flexibility in their oversight and regulation to accommodate new evidence and learning on nanomaterials;
- Consistent with current statutes and regulations, strive to reach an appropriate level of consistency in risk assessment and risk management across the Federal Government, using standard oversight approaches to assess risks and benefits and manage risks, considering safety, health and environmental impacts, and exposure mitigation;
- Mandate risk management actions appropriate to, and commensurate with, the degree of risk identified in an assessment;
- Seek to coordinate with one another, with state authorities, and with stakeholders to address the breadth of issues, including health and safety, economic, environmental, and ethical issues (where applicable) associated with nanomaterials; and
- Encourage coordinated and collaborative research across the international community and clearly communicate the regulatory approaches and understanding of the United States to other nations."[2]

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[1]White House Office of Science and Technology Policy. (March 11, 2011). Principles for Regulation and Oversight of Emerging Technologies. Retrieved from http://www.whitehouse.gov/sites/default/files/microsites/ostp/etipc-memo-3-11-2011.pdf

[2]White House Office of Science and Technology Policy. (June 29, 2011). Policy Principles for the U.S. Decision-Making Concerning Regulation and Oversight of Applications of Nanotechnology and Nanomaterials. Retrieved from http://www.whitehouse.gov/sites/default/files/omb/inforeg/for-agencies/nanotechnology-regulation-and-oversight-principles.pdf

researcher at PEN, which undertook the most comprehensive review of applicable laws to date, wrote that all of these laws:

> …either suffer from major shortcomings of legal authority, or from a gross lack of resources, or both. They provide a very weak basis for identifying and protecting the public from potential risk, especially as nanotechnologies become more complex in structure and function and the applications become more diverse.[40]

FDA

The U.S. Food and Drug Administration (FDA) regulates a wide range of products, including foods, cosmetics, drugs, devices, veterinary products and tobacco products that may utilize nanotechnology or contain nanomaterials. The FDA maintains that its current framework for safety assessments is appropriate for nanomaterials and that its review processes can adequately protect the public from potential risks associated with the use of nanomaterials. As the U.S. Food and Drug Administation says in a discussion on nanotechnology on its website, the "FDA has long encountered the combination of promise, risk, and uncertainty that accompanies emerging technologies. Nanotechnology is not unique in this regard."[41] The FDA has identified increased nanotechnology regulatory science research and up-to-date training of staff members who evaluate marketing applications for drug products developed using nanomaterials as areas in need of improvement, however.[42]

An FDA Nanotechnology Task Force recommended in July 2007 that the FDA provide assistance to manufacturers when the use of nanomaterials might require submission of additional data, change the product's regulatory status or pathway or merit taking additional or special steps to address potential safety or product quality issues. The FDA has not issued specific regulations for manufacturers with respect to nanomaterials, but in June 2014 it issued three final guidances for industry that acknowledge there are differences between nanomaterials and their bulk counterparts, and that nanomaterials have potential new risks and may require new testing. The first guidance presents the FDA's thinking on considerations related to nanotechnology. The FDA also published two product-specific draft guidances for the food and cosmetics industries and a draft guidance that addresses issues related to the use of nanotechnology in food ingredients intended for use in food for animals. When releasing the guidances the FDA noted that it "does not make a categorical judgment that nanotechnology is inherently safe or harmful, and will continue to consider the specific characteristics of individual products."[43] The FDA also encourages manufacturers to consult with the agency before taking their products to market. To follow are key points of the three FDA final guidances:

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[40]Davies, J. C. Project on Emerging Nanotechnologies, Woodrow Wilson International Center for Scholars. (January 2006). Managing the Effects of Nanotechnology. Retrieved from http://www.nanotechproject.org/process/assets/files/2708/30_pen2_mngeffects.pdf

[41]U.S. Food and Drug Administration. (June 24, 2014). FDA's Approach to Regulation of Nanotechnology Products. Retrieved from http://www.fda.gov/ScienceResearch/SpecialTopics/Nanotechnology/ucm301114.htm

[42]Cruz, C. (October 24, 2013). As nanotechnology is being used to develop new drugs, FDA is working to ensure quality, safety, and effectiveness. Retrieved from http://blogs.fda.gov/fdavoice/index.php/2013/10/as-nanotechnology-is-being-used-to-develop-new-drugs-fda-is-working-to-ensure-quality-safety-and-effectiveness/

[43]U.S. Food and Drug Administration. (June 24, 2104). FDA issues guidance to support the responsible development of nanotechnology products. Retrieved from http://www.fda.gov/NewsEvents/Newsroom/PressAnnouncements/ucm402499.htm

- ***Considering Whether an FDA-Regulated Product Involves the Application of Nanotechnology***[44]
  - Focuses on properties in addition to size; in addition to addressing engineered materials or end products in the nanoscale range (approximately 1 to 100 nm), the guidance addresses engineered material or end products that exhibit properties or phenomena that are attributable to their dimension(s), even if these dimensions fall outside the nanoscale range, up to 1,000 nm. *(See Box 6 on Nanotechnology Definitions, p. 38-40.)*
  - Adheres to Policy Principles released in 2011 by the White House Office of Science & Technology. *(See Box 7, p. 43.)*
  - Notes that these considerations apply not only to new products, but also when manufacturing changes alter the dimensions, properties or effects of an FDA-regulated product or any of its constituent parts.
- ***Assessing the Effects of Significant Manufacturing Process Changes, Including Emerging Technologies, on the Safety and Regulatory Status of Food Ingredients and Food Contact Substances, Including Food Ingredients that are Color Additives***[45]
  - Describes the factors manufacturers should consider when determining whether a significant change in manufacturing process for a food substance already in the market:
    - Affects the identity of the food substance;
    - Affects the safety of the use of the food substance;
    - Affects the regulatory status of the use of the food substance; and
    - Warrants a regulatory submission to FDA.
  - Suggests companies will have to provide additional testing data for products with engineered nanomaterials in most instances. Companies are not required to seek premarket review and approval for products containing any food ingredient or food contact substance [FCS] if it is generally recognized as safe [GRAS]. The guidance states that "a food substance manufactured for the purpose of creating very small particle sizes with new functional properties likely would not be covered by an existing GRAS determination for a related food substance manufactured without using nanotechnology."
- ***Safety of Nanomaterials in Cosmetic Products***[46]
  - Notes that traditional toxicity testing methods should be modified or new methods developed to address:
    1. the key chemical and physical properties that may affect the toxicity profile of nanomaterials, and
    2. the effects of those properties on the function of the cosmetic formulation.
  - Notes that in some cases traditional safety testing methods may not be fully applicable due to a nanomaterial's distinctive properties and behavior.

Unlike food products, cosmetics are not subject to mandatory premarket approval. The FDA does not have authority to require cosmetic companies to submit safety data; but companies are legally respon-

[44] U.S. Food and Drug Administration. (June 2014). Considering Whether an FDA-Regulated Product Involves the Application of Nanotechnology. Retrieved from http://www.fda.gov/regulatoryinformation/guidances/ucm257698.htm

[45] U.S. Food and Drug Administration. (June 2014). Guidance for Industry: Assessing the Effects of Significant Manufacturing Process Changes, Including Emerging Technologies, on the Safety and Regulatory Status of Food Ingredients and Food Contact Substances, Including Food Ingredients that are Color Additives. Retrieved from http://www.fda.gov/Food/GuidanceRegulation/GuidanceDocumentsRegulatoryInformation/ucm300661.htm

[46] U.S. Food and Drug Administration. (June 2014). Guidance for Industry: Safety of Nanomaterials in Cosmetic Products. Retrieved from http://www.fda.gov/Cosmetics/GuidanceRegulation/GuidanceDocuments/ucm300886.htm

sible for assuring that their products are safe and properly labeled. To provide oversight, the FDA relies on publicly available or voluntarily submitted information, adverse event reporting (where applicable) and on post-market surveillance activities.[47] Pending legislation, the Safe Cosmetics and Personal Care Products Act of 2013, would give the FDA increased authority, including reviewing nanomaterials in cosmetics, but it remains in committee and is not expected to progress in the current Congress.

EPA

The EPA currently[48] addresses nanotechnology under two key regulatory initiatives:

- **Toxic Substances Control Act (TSCA)**
- **Federal Insecticide, Fungicide and Rodenticide Act (FIFRA)**

TSCA: The law aims to allow EPA to regulate new commercial chemicals before they enter the market, and to regulate significant new uses that might alter the effects of existing chemicals. Many nanoscale materials are regarded as “chemical substances” under TSCA. At issue is whether materials in nano form that are in a TSCA approved inventory in bulk form should be considered “new” or “existing” chemical substances. If a substance is on the approved list, it can be used in commerce. Alternatively, producers of a “new” material must provide EPA with a pre-manufacture notification (PMN). EPA then has 90 days to approve manufacture, to require information from manufacturers, or to restrict chemical use. The EPA also can issue provisional approvals that allow companies to provide additional data over time while developing materials in small amounts.

At present, the EPA considers nanomaterials to be existing chemicals and does not review them under TSCA if they are in the TSCA inventory in bulk form, although the EPA has proposed changing this approach. In January 2008, EPA published *TSCA Inventory Status of Nanoscale Substances – General Approach*[49] to describe its initial thinking on this issue. The EPA indicated it would base its determination on whether the chemical substance has the same molecular identity as a substance already on the Inventory, rather than focus on physical attributes such as particle size. The EPA added that even if a nanoscale substance differed in certain physical and/or chemical properties resulting from the difference

[47]U.S. Food and Drug Administration. (June 24, 2014). FDA’s Approach to Regulation of Nanotechnology Products. Retrieved from http://www.fda.gov/ScienceResearch/SpecialTopics/Nanotechnology/ucm301114.htm

[48]A voluntary EPA initiative, the Nanoscale Materials Stewardship Program (NSPM) ran from 2008 to 2009 and sought to provide a firmer scientific foundation for regulation under TSCA. The NMSP had two parts: 1) a Basic Program for reporting available information on engineered nanoscale materials, including material characterization, hazard, use, potential exposures, and risk management practices; and 2) an In-depth Program to voluntarily test engineered nanoscale materials and develop data. The program had limited participation. According to a January 2009 NMSP Interim Report, “approximately 90% of the different nanoscale materials that are likely to be commercially available were not reported under the Basic Program.” Only 31 entities, including four S&P 500 companies—**Dow Chemical, DuPont, General Electric** and **PPG Industries**—participated in the Basic Program. Just 4 companies (and none of the S&P 500 companies) had agreed to participate in the In-depth Program by December 2008. See U.S. Environmental Protection Agency Office of Pollution Prevention and Toxics. (January 2009). Nanoscale Materials Stewardship Program Interim Report. Retrieved from http://www.epa.gov/oppt/nano/nmsp-interim-report-final.pdf. Also: U.S. Environmental Protection Agency. (June 5, 2013). Nanoscale Materials Stewardship Program. Retrieved from http://www.epa.gov/oppt/nano/stewardship.htm.

[49]U.S. Environmental Protection Agency. (January 23, 2008). TSCA Inventory Status of Nanoscale Substances – General Approach. Retrieved from http://www.epa.gov/oppt/nano/nmsp-inventorypaper2008.pdf

in particle size, the EPA would consider the two forms to be the same chemical substance because they have the same molecular identity.[50]

Although molecular identity is not defined in the statute, EPA considers chemicals to have different molecular identities when, for example, they represent different allotropes—a variant of a substance consisting of only one type of atom—or isotopes. Accordingly, nanoscale versions of titanium dioxide, which have the same molecular formula as titanium dioxide, would not be considered a new chemical under TSCA because titanium dioxide is in the inventory. Conversely, fullerenes—a class of nanomaterials made of spheres of carbon—would be considered a new chemical because they represent a different allotrope, or molecular arrangement of carbon atoms, than those chemicals already listed on the inventory.[51] To clarify some confusion regarding carbon-based nanomaterials, the EPA subsequently published a Federal Register Notice on carbon nanotubes (CNTs) in October 2008. It stated that the EPA generally considers CNTs to be distinct chemical substances from graphite or other allotropes of carbon listed on the TSCA Inventory.[52]

Altogether, the EPA has received and reviewed, on a case-by-case basis, more than 100 new chemical notices for nanoscale materials under TSCA Since 2005.[53] More than half are carbon-based, and the bulk of the remaining are new materials not identified to the public because of confidential business information claims.[54] Unions and environmental, workplace and community health groups have objected to many of EPA's Significant New Use Rules (SNURs) for nanomaterials, saying that EPA's testing recommendations are highly inadequate and that the EPA has not provided evidence that its required measures will provide adequate protection.[55]

Attempted new approach—In 2009, the EPA announced it was working on a SNUR for nanoscale materials. Early indications were that the rule would represent a significant change in approach in that it would be quite sweeping and applicable to all nanoscale materials, except for existing commercial uses that would have a grandfathered exemption. The proposed SNUR would require persons who intend to manufacture, import or process new nanoscale materials based on chemical substances listed on the TSCA Inventory to submit a Significant New Use Notice (SNUN).[56] The draft SNUR was forwarded

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[50]U.S. Environmental Protection Agency. (January 23, 2008). TSCA Inventory Status of Nanoscale Substances – General Approach. Retrieved from http://www.epa.gov/oppt/nano/nmsp-inventorypaper2008.pdf

[51]U.S. Government Accountability Office. (May 2010). Nanotechnology: Nanomaterials Are Widely Used in Commerce, but EPA Faces Challenges in Regulating Risk. Retrieved from http://www.gao.gov/assets/310/304648.pdf

[52]U.S. Environmental Protection Agency. (October 31, 2008). Toxic Substances Control Act Inventory Status of Carbon Nanotubes. Retrieved from http://www.gpo.gov/fdsys/pkg/FR-2008-10-31/pdf/E8-26026.pdf

[53]U.S. Environmental Protection Agency. (April 29, 2011). Control of Nanoscale Materials under the Toxic Substances Control Act. Retrieved from http://www.epa.gov/oppt/nano/index.html

[54]Canada-US Regulatory Cooperation Council. (November 28, 2012). Nanotechnology Initiative Stakeholder Webinar, Retrieved from http://nanotech.lawbc.com/uploads/file/00105620.PDF

[55]Link no longer active. Kojola, B., AFL-CIO and Sass, J. Natural Resources Defense Council. (March 19, 2012). Comment submitted by Bill Kojola, Department of Occupational Safety and Health, AFL-CIO and Jennifer Sass, Ph.D., Senior Scientist, Natural Resources Defense Council (NRDC).
http://federal.eregulations.us/rulemaking/document/EPA-HQ-OPPT-2010-0279-0130

[56]U.S. Environmental Protection Agency. (April 29, 2011). Control of Nanoscale Materials under the Toxic Substances Control Act. Retrieved from http://www.epa.gov/oppt/nano/index.html

to the Office of Management and Budget in 2010 and remains there. TSCA also gives EPA authority to issue rules requiring companies to submit certain information about chemicals. Reports that the EPA also intended to use its authority under TSCA to issue rules requiring companies to submit certain information about nanomaterials also have never come to pass.[57]

FIFRA: EPA regulates products intended to control pests under the authority of FIFRA**.** Producers of pesticide products are required to submit scientific and technical data for EPA review to ensure that the use of a pesticide will not generally cause unreasonable adverse effects on human health or the environment. Because FDA approval is use-specific, FIFRA provides the EPA more latitude for review than TSCA.

In June 2011, the EPA issued a Federal Register notice on nanomaterials under FIFRA. The EPA sought comments on several possible approaches for obtaining information about nanoscale materials that would apply to already registered products as well as products pending registration. The EPA also proposed initially classifying any application containing a nanoscale material as an application for a "new" active or inert ingredient, including when an identical, non-nanoscale form of the nanoscale ingredient is already registered under FIFRA.[58] The comment period, which saw strong pushback from industry, closed in 2011, and the EPA has not released any further information.[59]

In the meantime, the EPA is addressing nano products on a case-by-case basis under FIFRA. In November 2013, a court of appeals agreed with the Natural Resources Defense Council that the EPA had improperly approved a product containing nanosilver under FIFRA. *(See Box 3 on Nanosilver for more, p. 29.)* More recently, in March 2014, the EPA ordered the private firm Pathway Investment to stop selling plastic food storage containers containing nanosilver that had not been tested or registered with the EPA. The company claimed that nanosilver reduced the growth of mold, fungus and bacteria. The EPA also issued warning letters to Amazon, Sears, Wal-Mart and other large retailers directing them not to sell these products.[60]

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[57]U.S. Government Accountability Office. (May 2010). Nanotechnology: Nanomaterials Are Widely Used in Commerce, but EPA Faces Challenges in Regulating Risk. Retrieved from http://www.gao.gov/assets/310/304648.pdf

[58]U.S. Environmental Protection Agency. (June 17, 2011). Pesticides: Policies Concerning Products Containing Nanoscale Materials. Retrieved from http://www.regulations.gov/#!documentDetail;D=EPA-HQ-OPP-2010-0197-0001

[59]See comments from the American Chemistry Council, Chemical Producers & Distributors Association, Consumer Specialty Products Association, NanoBusiness Commercialization Alliance and Nanotechnology Coalition (a trade association affiliated with the Society of Chemical Manufacturers and Affiliates). (August 2011). Retrieved from http://www.regulations.gov/#!docketBrowser;rpp=25;po=0;dct=PS;D=EPA-HQ-OPP-2010-0197;refD=EPA-HQ-OPP-2010-0197-0001

[60]U.S. Environmental Protection Agency. (March 31, 2014). EPA Takes Action to Protect Public from an Illegal Nano Silver Pesticide in Food Containers; Cites NJ Company for Selling Food Containers with an Unregistered Pesticide Warns Large Retailers Not to Sell These Products. Retrieved from http://yosemite.epa.gov/opa/admpress.nsf/d0cf6618525a9efb85257359003fb69d/6469952cdbc19a4585257cac0053e637!OpenDocument

CPSC

The Consumer Product Safety Commission (CPSC) is responsible for protecting consumers from products that pose a fire, electrical, chemical or mechanical hazard, or can injure children. In response to members of Congress' directive to review the utilization and safety of nanotechnology in consumer products, the CPSC requested additional funding in 2011 to collect data on nanomaterials use in consumer products. Planned programs include working with other agencies on:

1) developing protocols to assess the potential release of airborne nanoparticles from various consumer products and to determine their contributions to human exposure;
2) determining whether nanomaterials can be used for performance improvement in sports safety equipment such as helmets and kneepads without creating other health hazards;
3) expanding consumer product testing using scientifically credible protocols to evaluate the exposure potential from nanosilver in consumer products, with special emphasis on exposures to young children; and
4) working across agencies to assure that shared common public health concerns are met in research studies to determine potential impacts on the public health of nanomaterial use in consumer products.[61]

The CPSC staff identifies products that claim or are believed to contain nanomaterials and maintains a database with information on these products. Given that there are no pre-market notifications, the staff may not be aware of the products that contain nanomaterials and the specific nanomaterials incorporated in these products.[62]

Workers

An estimated 400,000 researchers and workers, including 150,000 in the United States, were involved in one domain or another of nanotechnology in 2008. In 2014, the European Commission estimates that current direct employment in the nanomaterial sector in Europe alone totals 300,000 to 400,000 workers.[63] Trends suggest that the number of nanotechnology workers worldwide will reach six million workers by 2020, including two million in the United States.[64] These workers have the greatest exposure to nanomaterials, and they are dependent on companies following recommended guidelines. Currently, there are no established regulatory occupational exposure limits (OELs) for nanomaterials in the United States, although NIOSH (which is not a regulatory agency) has published guidelines on the safe use of engineered nanomaterials. NIOSH also has issued two recommended exposure limits for nanomaterials (see below). The British Standards Institute and Germany's Institut für Arbeitsschutz der Deutschen Gesetzlichen Unfallversicherung, an institute for worker safety, have recommended exposure control if a nanomaterial meets certain characteristics, such as size, solubility, shape and potential health concerns

[61]National Nanotechnology Initiative. (n.d.). U.S. Consumer Product Safety Commission. Retrieved from http://www.nano.gov/node/139

[62]Rejeski, D. Woodrow Wilson International Center for Scholars.(August 25, 2009). Oral Presentation on CPSC FY2010 Agenda and Priorities. Retrieved from http://www.cpsc.gov/PageFiles/90427/2011priorities.pdf

[63]Policy Issues. European Commission. (n.d.) Retrieved from http://ec.europa.eu/research/industrial_technologies/policy_en.html

[64]Roco, M., Mirkin, C. and Hersam, M. (September 30, 2010). Nanotechnology Research Directions for Societal Directions in 2020, Retrieved from http://www.wtec.org/Nano_Research_Directions_to_2020.pdf

Box 8
Carbon Nanotubes

Carbon nanotubes (CNT) and nanofibers (CNF) are illustrative of many things "nano": the promise of nanomaterials, the challenge of investing in them and the potential impacts of engineered nanomaterials on human health. CNTs and CNFs have the potential to be used in a wide range of applications. Modified CNTs have the potential to dramatically strengthen material or increase a product's efficiency; improve conductivity; detect faint traces of chemicals; filter toxic chemicals and biological contaminants; and enter cells and deliver drugs or eliminate unwanted genes.

Carbon nanotubes also are well known among investors for failing to produce commercial successes. As a Lux Research analyst cautioned, "The rocky history of carbon nanotubes shows that a research and patent boom along with impressive technical performance is far from a guarantee of commercial success, as major challenges like high costs, processing issues, and competing emerging material classes loom large."[1]

Results from recent animal studies indicate that some forms of CNT and CNF may have similar effects as asbestos and be capable of causing pulmonary toxicity, fibrosis and cancer if workers inhale them. Yet because these nanomaterials are relatively new, much of the occupational exposure has occurred at the research and development or pilot stage, and there have been few reliable surveys of the size of the workforce exposed to them. In September 2012, the National Institute for Occupational Safety and Health (NIOSH) announced plans for a new exposure assessment and epidemiological study of U.S. workers exposed to CNTs and CNFs. A notice in the Federal Register regarding this study stated:

> Carbon nanotubes and nanofibers are among the nanomaterials of greatest interest from a public health perspective because of their potentially asbestiform properties (e.g., high aspect ratio) and toxicological evidence of possible fibrogenic, inflammatory, and clastogenic damage resulting from exposures at occupationally relevant levels. In addition, the useful properties of CNT and CNF have rendered them among the first nanomaterials to be commercially exploited in manufacturing settings. Thus, an epidemiologic study to determine whether early or late health effects occur from occupational exposure to CNT and CNF is warranted.[2]

In 2013, NIOSH published recommended exposure limits for carbon nanotubes and carbon nanofibers. The only other nanomaterial for which it has done the same is titanium dioxide.

[1]Kozarsky, R. Lux Research. (December 2012). Is Graphene the Next Silicon ... Or Just the Next Carbon Nanotube? Retrieved from https://portal.luxresearchinc.com/research/report_excerpt/12415.
[2]Department of Health and Human Services. (September 20, 2012). Proposed Data Collections Submitted for Public Comment and Recommendations. Retrieved from http://www.nanotechproject.org/process/assets/files/9239/niosh_nano.pdf

as related to larger particles of the same substance; neither institute offers recommendations specific to any one nanomaterial. Some companies, such as Bayer, have supplied suggested occupational exposure limits for their products.[65]

[65]National Institute for Occupational Safety and Health. (November 2013). Current Strategies for Engineering Controls in Nanomaterial Production and Downstream Handling Processes. Retrieved from http://www.cdc.gov/niosh/docs/2014-102/. Also Geraci, C. (March 3, 2014.) Personal communication.

U.S. agencies have cited the lack of data as a key reason for not regulating exposure levels. NIOSH reported in November 2013 that it is difficult to determine or even estimate a safe exposure level given the lack of regulatory standards and formal recommendations for many nanomaterials in the United States.[66] The Centers for Disease Control and Prevention also noted the challenges it faces on its website:

> Occupational health risks associated with manufacturing and using nanomaterials are not yet clearly understood. Minimal information is currently available on dominant exposure routes, potential exposure levels, and material toxicity of nanomaterials.

NIOSH guidance and bulletins—NIOSH published two current intelligence bulletins (CIBs) recommending exposure limits for titanium dioxide in 2011 and carbon nanotubes and nanofibers in 2013.[67] The EPA has cited these limits as part of its significant new use rules for specific nanomaterials. In addition, in September 2012 NIOSH announced plans for a new exposure assessment and epidemiological study of U.S. workers exposed to CNTs and CNFs. *(See Box 8 on Carbon Nanotubes, p. 50.)*

In addition to its two recommended OELs, NIOSH published a November 2013 document that identifies and describes strategies for the engineering control of worker exposure during the production or use of engineered nanomaterials. NIOSH also published recommendations on engineering controls and safe practices for handling engineered nanomaterials in laboratories and some pilot scale operations in May 2012.[68] In 2009, the agency published a document reviewing what then was known about nanoparticle toxicity, process emissions and exposure assessment, engineering controls and personal protective equipment. NIOSH noted that the 2009 document served a dual purpose:

> It is a summary of NIOSH's current thinking and interim recommendations; and it is a request from NIOSH to occupational safety and health practitioners, researchers, product innovators and manufacturers, employers, workers, interest group members, and the general public to exchange information that will ensure that no worker suffers material impairment of safety or health as nanotechnology develops.[69]

In April 2013, the Occupational Safety and Health Administration (which does have authority to set and enforce standards) published a fact sheet to provide basic information to workers and employers on potential hazards associated with nanotechnology and to highlight measures to control exposure to nanomaterials in the workplace.[70]

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[66]National Institute for Occupational Safety and Health. (November 2013). Current Strategies for Engineering Controls in Nanomaterial Production and Downstream Handling Processes. Retrieved from http://www.cdc.gov/niosh/docs/2014-102/

[67]National Institute for Occupational Safety and Health. (2011). Current Intelligence Bulletin 63: Occupational Exposure to Titanium Dioxide. Retrieved from http://www.cdc.gov/niosh/docs/2011-160/; National Institute for Occupational Safety and Health. (2013). Current Intelligence Bulletin 65: Occupational Exposure to Carbon Nanotubes and Nanofibers. Retieved from http://www.cdc.gov/niosh/docs/2013-145/

[68]National Institute for Occupational Safety and Health. (May 2012). General Safe Practices for Working With Engineered Nanomaterials in Research Laboratories. Retrieved from http://www.cdc.gov/niosh/docs/2012-147/

[69]National Institute for Occupational Safety and Health. (March 2009). Approaches to Safe Nanotechnology: Managing the Health and Safety Concerns Associated with Engineered Nanomaterials. Retrieved from http://www.cdc.gov/niosh/docs/2009-125/

[70]Occupational Safety and Health Administration. (April 2013). OSHA FactSheet: Working Safely with Nanomaterials. Retrieved from https://www.osha.gov/Publications/OSHA_FS-3634.pdf

Shareholder Engagement

Members of the Interfaith Center on Corporate Responsibility (ICCR), primarily As You Sow and Calvert Investments, have been engaging corporations on the issue of nanotechnology since 2008.[71] As You Sow has continued to focus on this issue and most recently garnered support for a nanomaterials shareholder resolution from nearly 20 percent of the shares voted at **Dunkin' Brands** 2014 annual meeting. In addition to the companies identified below in the discussion of work by Calvert Investment and As You Sow on this issue, ICCR members indicated to Si2 they also have held dialogues on nanotechnology with **E.I. DuPont de Nemours**, **Estee Lauder, Henkel AG, Johnson & Johnson, Procter & Gamble, Sara Lee** and **Unilever**.

Calvert Investments: In 2008 and 2009, Calvert Investments filed four shareholder resolutions at **Avon, Colgate-Palmolive** and **Kellogg**. A 2008 nanomaterial product safety resolution at Avon was supported by 25.4 percent of the shares voted, and a resubmission in 2009 received support from 10.7 percent. The resolved clause of the 2008 resolution stated:

> Resolved: Shareholders request that the Board publish a report to shareholders on Avon's policies on nanomaterial product safety, at reasonable expense and omitting proprietary information, by November 1, 2008. This report should identify Avon product categories that currently contain nanomaterials, and discuss any new initiatives or actions, aside from regulatory compliance, that management is taking to respond to this public policy challenge.

Calvert Investments withdrew the same resolution at Colgate-Palmolive in 2008 after the company provided the requested information. In 2009, Calvert withdrew a similar resolution focused on the use of nanomaterials in both products and packaging at Kellogg after the company agreed to publish a policy in its corporate responsibility report.

As You Sow: Upon hearing reports of a surge of nanomaterials in the food industry, As You Sow, a non-profit organization that promotes environmental and social corporate responsibility, began a shareholder advocacy campaign in 2008. In addition to filing shareholder resolutions, As You Sow's work on nanotechnology has included dialogue with companies, two reports, an industry survey and product testing, on the following timeline:[72]

- **2008:** As You Sow filed its first shareholder resolutions on nanomaterials. The resolution asked **Wal-Mart's** board of directors to publish a report on company policies on nanomaterial product safety. The U.S. Securities and Exchange Commission allowed Wal-Mart to omit the resolution on ordinary business grounds, and it was not voted upon by shareholders.

[71] Si2 has collaborated with As You Sow to publish *Proxy Preview*, a forecast of the U.S. proxy season, but Si2 does not participate in any of its advocacy efforts.

[72] Additional information on As You Sow's work on nanomaterials can be found at http://www.asyousow.org/health_safety/gmosnano.shtml

- **2009:** As You Sow filed and withdrew shareholder resolutions on nanomaterials and food safety at **McDonald's** and **Kraft Foods**. The resolutions asked each company to "Report on policies on use of nanomaterials in products and packaging; identify product or packaging categories that contain nanomaterials, and discuss any initiatives or actions management is taking to reduce or eliminate potential human health impacts." As You Sow withdrew the two resolutions after:
    - McDonalds publicly stated it "does not currently support the use by suppliers of nano-engineered materials in the production of any of our food, packaging, and toys." Prior to issuing its statement, McDonald's participated in a video conference and briefing organized by As You Sow that included corporate, scientific and NGO speakers.
    - Kraft Foods posted the following statement on its website: "Currently we're not using nanotechnology. But as a leading food company, we need to understand the potential this technology may hold for us in terms of food safety, product quality, nutrition and sustainability." Prior to issuing its statement, Kraft senior management met with several investor groups in New York to discuss this issue.
- **2010:** Working with other investor firms, As You Sow contacted additional global food companies, including **YUM! Brands**, **PepsiCo** and **Whole Foods**, about their use of nanomaterials. As You Sow found that none of the companies contacted were using nanomaterials, yet most were not initially aware if they were or not.

- **2011:** Concerned about what it viewed as a lack of corporate knowledge about nanomaterials, As You Sow produced a Sourcing Framework.[73] The *Framework* provides guidelines for food and food packaging companies to assess their exposure to, and the potential risks of, sourcing products that contain nanomaterials. The *Framework* also includes recommendations on what information companies should obtain from suppliers regarding safety testing of nanomaterials and products containing nanomaterials.

- **2012:** As You Sow surveyed 2,500 companies to gain a more accurate understanding of corporate policies and the status of nanomaterial use in the U.S. food market. As You Sow received 26 responses; an additional 38 companies responded to follow-up Facebook inquiries. In an online search, As You Sow found a variety of news articles indicating that at least 69 of the surveyed companies had an interest in nanotechnology or were currently producing products containing nanomaterials.

  As You Sow also conducted independent laboratory tests on donuts with white powdered sugar frosting. It found titanium dioxide nanoparticles in both **Dunkin' Donuts** Powdered Cake Donuts and **Hostess** Donettes. Whether the particles were engineered or a byproduct of the manufacturing process is not known.

- **2013:** As You Sow published Slipping through the Cracks[74] to inform companies, investors and consumers about the emerging use of engineered nanomaterials in food and food related prod-

[73]As You Sow. (December 2011). Sourcing Framework for Food and Food Packaging Products Containing Nanomaterials. Retrieved from http://www.asyousow.org/ays_report/sourcing-framework-for-food-and-food-packaging-products-containing-nanomaterials/

[74]As You Sow. (February 2013). Slipping Through the Cracks: An Issue Brief on Nanomaterials in Foods. Retrieved from http://www.asyousow.org/health_safety/nanoissuebrief.shtml. The Investor Environmental Health Network (IEHN) worked with Calvert and As You Sow on these resolutions and dialogues. IEHN also has published reports that address corporate reporting on this issue, including Lewis, S. (2008). Toxic Stock Syndrome: How Corporate Financial Reports Fail to Apprise Investors of the Risks of Product Recalls and Toxic Liabilities. Retrieved from

ucts. The report highlights the potential risks of nanotechnology for public health and for companies that are knowingly or unknowingly using it in their products.

As You Sow also ran an online crowd funding campaign to test M&Ms (manufactured by **Mars**) and Pop-Tarts (manufactured by **Kellogg**), among other foods, and reported finding nanomaterials in these products.

- **2014:** As You Sow's shareholder resolution filed at **Dunkin' Brands** received support from 18.6 percent of the shares voted. The resolution says that **"**titanium-dioxide nanomaterials are likely being used in Dunkin' Donuts without adequate testing to ensure safety, and without notice or warning of their presence or potential hazard." The resolved clause of the shareholder resolution states:

> Shareholders request the Board publish by November 1, 2014, at reasonable cost and excluding proprietary information, a report on Dunkin's policies regarding public health concerns of nanomaterials in the company's products or packaging. This report should identify products or packaging that currently contains nanomaterials, and discuss any actions, aside from regulatory compliance, management is taking to reduce or eliminate risk associated with human health and environmental impacts, such as eliminating, or disclosing, the use of nanomaterials until they are proven safe through long-term testing.

Future projections: As You Sow reports to Si2 that it plans to continue its "work to improve industry knowledge about nanomaterials and to prevent the unlabeled use of nanomaterials in foods until proven safe for humans and the environment." It says it is testing additional food products to determine the presence of nanomaterials, with results for 15 more popular products expected by fall 2014. The organization also is working with the food industry to create strong and consistent nanomaterials policies. It says, "Where no progress is being made with companies using nanomaterials in foods, As You Sow expects to file resolutions to ensure that the company is addressing the likely risks associated with using nanomaterials in foods."

http://iehn.org/documents/IEHN%20Toxic%20Stock%20Report%203-08.pdf and IEHN. (2009). Bridging the Credibility Gap: Eight Corporate Liability Accounting Loopholes That Regulators Must Close. Retrieved from http://iehn.org/documents/EightLoopholes.pdf.

Appendix A

"Nano" References in Form 10-Ks of S&P 500 Companies

(References highlighted in yellow)
Si2 reviewed most recent Form 10-Ks in 4th quarter 2013

Abbott Laboratories

Item 1. Business Description
Vascular Products

The principal products included in the Vascular Products segment are:

- Xience Xpedition®, Xience Prime®, Xience nano™, and Xience V®, drug-eluting coronary stent systems developed on the Multi-Link Vision® platform;

Item 7. Management's Discussion and Analysis of Financial Condition and Results of Operations

Over the last three years, Abbott continued to build its *Xience* drug-eluting stent franchise with the receipt of approval to market *Xience Xpedition* in various countries, including U.S. approval in the fourth quarter of 2012 as well as the launches of *Xience nano* and *Xience PRIME* in the U.S. in 2011, and *Xience PRIME* and *Xience V* in Japan in April 2012 and January 2010, respectively. *Xience*, which includes *Xience V*, *PRIME, nano* and *Xpedition*, ended 2012 as the market-leading drug eluting stent globally. In 2011, the third party distributor of the Promus product began transitioning away from the product and that supply agreement ended in 2012. The effect of the winding down of the agreement will continue into the first quarter of 2013.

Agilent Technologies

Item 1. Business
The General Purpose Test Market

We address the biology, life sciences and material science markets by providing solutions such as the atomic force microscope, nano indenters and scanning electron microscope. For nanotechnology applications, customers use our products to study biological samples at the cellular and molecular level including imaging of DNA and proteins, and to study and research polymers, electrochemistry, and thin films.

General Purpose Test Products

Our semiconductor and board test solutions enable customers to develop and test state of the art semiconductors, test and inspect printed circuit boards, perform functional testing, and measure position and distance information to the sub-nanometer level. We supply parametric test instruments and systems used primarily to examine semiconductor wafers during the manufacturing process. Our in-circuit test system helps identify quality defects, such as faulty or incorrect parts, that affect electrical performance. Our laser interferometer measurement systems are based on precision optical technology and provide precise position or distance information for dimensional measurements.

Our atomic force microscopes ("AFM") are high-resolution imaging devices that can resolve features as small as an atomic lattice. An AFM allows researchers to observe and manipulate molecular and atomic level features. Our expanding portfolio of AFM products provides customers with reliable, easy-to-use tools for a wide range of nanotechnology applications, including semiconductor, data storage, polymers, materials science and life science studies.

Electronic Measurement Customers

Agilent's electronic measurement customers include original equipment and contract manufacturers of electronic products, wireless device manufacturers and network equipment manufacturers who design, develop, manufacture and install network equipment, service providers who implement, maintain and manage communication networks and services, and companies who design, develop, and manufacture semiconductors and semiconductor lithography systems. Our customers use our products to conduct research and development, manufacture, install and maintain radio frequency, microwave frequency, digital, semiconductor, and optical products and systems and conduct nanotechnology research. Many of our customers purchase solutions across several of our major product lines for their different business units.

Agilent Technologies Research Laboratories

The technical staff have advanced degrees that cover a wide range of scientific and engineering fields, including biology, chemistry, computer science, distributed measurement, electrical engineering, image processing, materials science, mathematics, nano/microfabrication, microfluidics, software, informatics, optics, physics, physiology and signal processing. As of the end of October 2013, Research Labs employed approximately 210 personnel worldwide.

Air Products & Chemicals

Item 6. Selected Financial Data

Certain items which management does not believe to be indicative of on-going business trends are considered non-GAAP items in our results discussions….For 2012, these items include: (i) a charge to operating income of $327 ($222 after-tax, or $1.03 per share) related to business restructuring and cost reduction plans, (ii) a gain of $86 ($55 after-tax, or $.25 per share) related to the gain on our previously held equity interest in DA NanoMaterials, (iii) a charge of $10 ($6 after-tax, or $.03 per share) related to a customer bankruptcy, (iv) a tax expense of $44 ($.20 per share) for a Spanish tax settlement, (v) a tax benefit of $58 ($.27 per share) for a favorable Spanish tax ruling.

Item 7. Management's Discussion and Analysis of Financial Condition and Results of Operations

The discussion of results that follows includes comparisons to non-GAAP financial measures. For 2013, the non-GAAP measures exclude the fourth quarter business restructuring and cost reduction plan and advisory costs. For 2012, the non-GAAP measures exclude the 2012 business restructuring and cost reduction plans (the photovoltaic (PV) market actions charge, the polyurethane intermediates (PUI) business actions charge, and the cost reduction plan charge), the customer bankruptcy charge, the gain on the previously held equity interest in DuPont Air Products NanoMaterials LLC (DA NanoMaterials), the Spanish tax settlement, and the Spanish tax ruling. For 2011, the non-GAAP measures exclude the net loss on Airgas transaction. The presentation of non-GAAP measures is intended to enhance the usefulness of financial information by providing measures that our management uses internally to evaluate our baseline performance on a comparable basis. The reconciliation of reported GAAP results to non-GAAP measures is presented on pages 29–31. Descriptions of the excluded items appear on pages 22–24.

RESULTS OF OPERATIONS
Discussion of Consolidated Results
2013 vs. 2012

Sales of $10,180.4 increased 6%, or $568.7. Underlying business decreased 1%, primarily due to lower volumes resulting from our previous decision to exit the PUI business and lower Electronics demand, partially offset by higher volumes in the Tonnage Gases, Performance Materials, and Equipment businesses. The acquisitions of Indura S.A. and DA NanoMaterials increased sales by 5%. Higher energy and raw material contractual cost pass-through to customers increased sales by 2%.

Operating Income
2013 vs. 2012

Operating income of $1,324.4 increased 3%, or $42.0. Current year operating income included a charge of $231.6 for a business restructuring and cost reduction plan and $10.1 for advisory costs. Prior year operating income included a charge of $327.4 for business restructuring and cost reduction plans, a $9.8 charge for a customer bankruptcy, and the gain on the previously held equity interest in DA NanoMaterials of $85.9. On a non-GAAP basis, operating income of $1,566.1 increased 2%, or $32.4. The increase was primarily due to acquisitions of $54, higher volumes of $24, and favorable currency translation and foreign exchange impacts of $2, partially offset by $40 from unfavorable higher energy and distribution costs net of pricing, and higher operating costs of $20, including the impact from pensions. Operating income increased by $12 from higher gains on the sale of assets and investments.

2012 vs. 2011

Operating income of $1,282.4 decreased 15%, or $225.7. Operating income in 2012 includes a charge of $327.4 for business restructuring and cost reduction plans, a $9.8 charge for a customer bankruptcy, and the gain on the previously held equity interest in DA NanoMaterials of $85.9. Operating income in 2011 includes a $48.5 net loss related to the Airgas transaction. On a non-GAAP basis, operating income of $1,533.7 decreased 1%, or $22.9. The decrease was primarily due to unfavorable volumes, including acquisitions, of $39 and unfavorable currency translation and foreign exchange impacts of $30, partially offset by lower costs of $31 and higher recovery of raw material costs in pricing of $15. The decrease in volumes was primarily from lower Merchant Gases volumes and unfavorable volume mix due to lower LNG plant sales.

Research and Development
2013 vs. 2012

Research and development expense of $133.7 increased 6%, or $7.3, primarily due to inflation and the acquisition of DA NanoMaterials. Research and development expense as a percent of sales was 1.3% in 2013 and 2012.

2012 vs. 2011

Research and development expense of $126.4 increased 6%, or $7.6, primarily due to the DA NanoMaterials acquisition. Research and development expense as a percent of sales increased to 1.3% from 1.2%.

Business Combinations
2012 Business Combinations

DA NanoMaterials LLC

On 2 April 2012, we closed on the acquisition agreement with E.I. DuPont de Nemours and Co., Inc. to acquire their 50% interest in our joint venture, DA NanoMaterials. Beginning in the third quarter of 2012, the results of DA NanoMaterials were consolidated within our Electronics and Performance Materials business segment.

Prior to the acquisition date, we accounted for our 50% interest in DA NanoMaterials as an equity-method investment. The year ended 30 September 2012 included a gain of $85.9 ($54.6 after-tax, or $.25 per share) as a result of revaluing our previously held equity interest to fair market value as of the acquisition date. Refer to Note 5, Business Combinations, to the consolidated financial statements for additional details on this transaction.

Effective Tax Rate
2013 vs. 2012

On a GAAP basis, the effective tax rate was 22.8% and 21.9% in 2013 and 2012, respectively. The current year rate includes income tax benefits of $73.7 related to the business restructuring and cost reduction plans and $3.7 for the advisory costs. The prior year rate includes income tax benefits of $105.0 related to the business restructuring and cost reduction plans, $58.3 related to bankruptcy charge, offset by income tax expense of $43.8 related to the first quarter Spanish tax settlement and $31.3 related to the gain on the previously held equity interest in DA NanoMaterials. Refer to Note 4, Business Restructuring and Cost Reduction Plans; Note 5, Business Combinations; Note 22, Income Taxes; and Note 23, Supplemental Information, to the consolidated financial statements for details on these transactions. On a non-GAAP basis, the effective tax rate was 24.2% in both 2013 and 2012.

2012 vs. 2011

On a GAAP basis, the effective tax rate was 21.9% and 24.3% in 2012 and 2011, respectively. The tax rate in 2012 includes income tax benefits of $105.0 related to the business restructuring and cost reduction plans, $58.3 related to the second quarter Spanish tax ruling, and $3.7 related to the customer bankruptcy charge, offset by income tax expense of $43.8 related to the first quarter Spanish tax settlement and $31.3 related to the gain on the previously held equity interest in DA NanoMaterials. Refer to Note 4, Business Restructuring and Cost Reduction Plans; Note 5, Business Combinations; Note 22, Income Taxes; and Note 23, Supplemental Information, to the consolidated financial statements for details on these transactions. The tax rate in 2011 includes an income tax benefit of $16.9 related to the Airgas transaction. Refer to Note 6, Airgas Transaction, to the consolidated financial statements for details on this transaction. On a non-GAAP basis, the effective tax rate was 24.2% and 24.6% in 2012 and 2011, respectively.

Electronics and Performance Materials

2013 vs. 2012

Sales decreased 3%, as lower volumes of 4% and lower pricing of 1% were partially offset by acquisitions of 2%. Electronics sales decreased 8%, as weaker materials volumes and equipment sales were partially offset by the acquisition of DA NanoMaterials. Performance Materials sales increased 2%, as higher volumes of 4% were partially offset by lower pricing of 2%. The increase in volumes was primarily due to strength in the automobile and U.S. housing markets partially offset by weaker volumes to certain construction markets and marine coatings. The lower pricing was primarily due to unfavorable mix impacts.

Operating income of $321.3 decreased 25%, or $104.3, and operating margin of 14.3% decreased 400 bp, as the prior year included a gain on the previously held equity interest in DA NanoMaterials of $85.9. On a non-GAAP basis, operating income of $321.3 decreased 5%, or $18.4, primarily from unfavorable price and mix impacts of $15, lower volumes of $9, and higher operating costs of $4 partially offset by higher acquisitions of $6 and favorable currency of $4. Operating margin decreased 30 bp, primarily due to lower volumes and unfavorable price mix.

2012 vs. 2011

Sales increased 1%, as acquisitions of 3% were partially offset by lower volumes of 1% and unfavorable currency of 1%. Electronics sales increased 3%, as the acquisition of DA NanoMaterials was partially offset by lower volumes of 2% and unfavorable currency of 1%. Performance Materials sales decreased 1%, as lower pricing of 1% and unfavorable currency of 1% were partially offset by higher volumes of 1%.

Operating income of $425.6 increased 18%, or $64.5, and operating margin of 18.3% increased 250 bp. Operating income in 2012 includes the gain on the previously held equity interest in DA NanoMaterials of $85.9. On a non-GAAP basis, operating income of $339.7 decreased 6%, or $21.4, primarily from unfavorable currency of $17 and lower recovery of raw material costs in pricing of $8, partially offset by lower operating costs of $3 and higher volumes, including acquisitions, of $1. Operating margin decreased 120 bp, primarily due to currency and volume mix.

LIQUIDITY AND CAPITAL RESOURCES
Operating Activities

For the year ended 2012, cash provided by operating activities was $1,765.1. Income from continuing operations of $999.2 reflected the non-cash gain on the previously held equity interest in DA NanoMaterials of $85.9, the write-down of long-lived assets associated with restructuring and a customer bankruptcy of $80.2, and a non-cash tax benefit of $58.3 recognized as a result of the second quarter Spanish tax ruling. The working capital accounts were a source of cash of $100.1. The provision for the cost reduction and business restructuring plans resulted in an increase to accrued liabilities of $223.9, partially offset by a use of cash of $32.9 for payments made in relation to these plans.

Capital Expenditures

In 2012, we acquired a controlling stake in Indura S.A. for $690 and E.I. DuPont de Nemours and Co., Inc.'s 50% interest in our joint venture, DA NanoMaterials for $147. We also purchased a 25% equity interest in Abdullah Hashim Industrial Gases & Equipment Co. Ltd. (AHG), an unconsolidated affiliate, for $155 in the third quarter.

Item 8. Financial Statements and Supplementary Data
Notes to the Consolidated Financial Statements
5. Business Combinations
2012 Business Combinations

DA NanoMaterials LLC

On 2 April 2012, we acquired E.I. DuPont de Nemours and Co. Inc.'s 50% interest in our joint venture, DuPont Air Products NanoMaterials LLC (DA NanoMaterials), for $158 ($147 net of cash acquired of $11). The transaction was accounted for as a business combination, and beginning in the third quarter of 2012, the results of DA NanoMaterials were consolidated within our Electronics and Performance Materials business segment.

Prior to the acquisition, we accounted for our 50% interest in DA NanoMaterials as an equity-method investment. The acquisition-date fair value of the previously held equity interest was valued at $120 and was determined using a discounted cash flow analysis under the income approach. The income approach required estimating a number of factors, including projected revenue growth, customer attrition rates, profit margin, and discount rate. The year ended 30 September 2012 includes a gain of $85.9 ($54.6 after-tax, or $.25 per share) as a result of revaluing our previously held equity interest to fair value as of the acquisition date. This gain is reflected on the consolidated income statements as "Gain on previously held equity interest.

8. Summarized Financial Information of Equity Affiliates

In the third quarter of 2012, we obtained control of DA NanoMaterials and began consolidating its results. Refer to Note 5, Business Combinations, for additional information. The unaudited amounts presented below include the results of DA NanoMaterials for 2011.

10. Goodwill

Merchant Gases goodwill increased during 2013, primarily due to the acquisitions of EPCO and WCG during the third quarter. Merchant Gases and Electronics and Performance Materials goodwill increased during 2012 due to the acquisition of Indura S.A. and DA NanoMaterials, respectively. Refer to Note 5, Business Combinations, for further details on these acquisitions.

25. Business Segment and Geographic Information
Business Segment
Operating Income
Electronics and Performance materials [(A)]

[(A)] Includes the gain on remeasuring our previously held equity interest in DA NanoMaterials. For additional information, see Note 5, Business Combinations.

Alcoa

Item 1. Business.
Research and Development

The Company continued its progress leveraging new science and technologies in 2012. For example, riblets that reduce aerodynamic drag have been analyzed and produced on a test basis. Self-cleaning nano coatings have been demonstrated on building products (an example of such was commercialized in 2011 as EcoClean, which is the world's first coil-coated aluminum architectural panel that helps clean itself and the air around it). Energy saving sensing devices are being integrated in Company manufacturing plants. Integrated thermal management products for consumer electronics have been developed and are being validated by our customers.

Altera

Item 1A. ***Risk Factors***

Our failure to define, develop and manufacture technologically advanced products would adversely affect the success and growth of our company.

We operate in a dynamic market characterized by rapid technological change. Our products are manufactured using a highly complex and precise process, requiring production in a tightly controlled environment. Our current product development efforts focus on developing new PLDs, related development software and hardware and advanced semiconductor wafer fabrication processes. Our development efforts may impact the timely introduction of competitive new products or product enhancements. Additionally, we may not be successful in developing new products or using and converting established products to new and more advanced process technologies. For example, our current generation product families, including the Stratix V family, are manufactured on a 28-nanometer process technology, but our next-generation product families will be manufactured on smaller circuit geometries that we have not used before. The use of advanced process technology has technological risks and start-up difficulties that can adversely affect research and development spending, yields, product costs and product delivery timeliness.

Item 7. Management's Discussion and Analysis of Financial Condition and Results of Operations
Results of Operations
Sales Overview

Net sales increased by 6% in 2011 from 2010, out-pacing the general semiconductor, ASIC, ASSP and PLD markets by a wide margin. The significant increase in *net sales* was primarily driven by strong growth in sales of our New and Mainstream Products. In 2011, with design incumbency from our 40-nanometer product success, our momentum continued in 28-nanometer, and our FPGA market share improved.

AMETEK

Item 1. Business
Financial Information about Reportable Segments, Foreign Operations and Export Sales
EIG
Process and Analytical Instrumentation Markets and Products

Process and analytical instrumentation sales represented 68% of EIG's 2012 net sales. These include: process analyzers; emission monitors; spectrometers, elemental and surface analysis instruments; level, pressure and temperature sensors and transmitters; radiation measurement devices; level measurement devices; precision pumping systems; force-materials and force-testing instruments; and radiation measurement devices. EIG's focus is on the process industries, including oil, gas and petrochemical refining, power generation, pharmaceutical manufacture, specialty gas production, water and waste treatment, natural gas distribution and semiconductor manufacturing. AMETEK's analytical instruments also are used for precision measurement in a number of other applications, including radiation detection, trace element and materials analysis, nanotechnology research, ultra precision manufacturing and test and measurement applications.

Applied Materials

Item 1. Business
Silicon Systems Group Segment

The majority of the Company's new equipment sales are for leading-edge technology for advanced nodes using 28 nanometer (nm) and smaller dimensions. To build a chip, the transistors, capacitors and other circuit components are first created on the surface of the wafer by performing a series of processes to deposit and selectively remove portions of successive film layers. Similar processes are then used to build the layers of wiring structures on the wafer. As the density of the circuit components increases to enable greater computing capability in the same or smaller physical area, the complexity of building the chip also increases, necessitating more process steps to form smaller transistor structures and more intricate wiring schemes. Advanced chip designs require more than 500 steps involving these and other processes to complete the manufacturing cycle.

Atomic Layer Deposition

ALD is an advanced technology in which atoms are deposited one layer at a time to build chip structures. This technology enables customers to fabricate thin films of either conducting or insulating material with uniform coverage in nanometer-sized structures. One of the most critical areas of the transistor is its gate, which is built by depositing layers of dielectric films. At the 22nm node and below, these film layers are so thin that they must be atomically engineered. The Applied Centura Integrated Gate Stack system features advanced ALD technology that builds ultrathin high-k film layers less than 2nm in thickness — about one hundred thousandth the width of a human hair.

Chemical Vapor Deposition

Low k Dielectric Films — Low k dielectric materials are used in copper-based chip designs to further improve interconnect speed. Using conventional CVD equipment, the Applied Producer Black Diamond® family of low k systems provides customers with a proven, cost-effective way to integrate a variety of low k films into advanced interconnect structures. The Company's latest third-generation low k technologies are featured on the Applied Producer Black Diamond 3 system and Applied Producer Nanocure 3 system. In addition, the Company offers its Applied Producer® Onyx™ process, an innovative film treatment that optimizes the molecular structure of low k films. Together, these products are designed to enable smaller, higher performance and more power-efficient devices at 22nm and below.

Lithography-Enabling Solutions — Applied offers several technologies on the Producer system to help chipmakers extend their current 193nm lithography tools, including a line of Applied APF® (advanced patterning film) films and Applied DARC® (dielectric anti-reflective coating) films. Together, they provide a film stack with the precise dimensional control and compatibility needed to cost-effectively pattern nano-scale features without additional integration complexity.

Gap Fill Films — There are many steps during the chipmaking process in which extremely small and deep, or high aspect ratio (HAR), structures must be filled void-free with a dielectric film. Many of these applications include the deposition of silicon oxides in substrate isolation structures, contacts and interconnects. Applied's most advanced gap fill system is its Applied Producer Eterna™ FCVD™ system. Targeted for 20nm and below chips, the Eterna system delivers a liquid-like film that flows freely into virtually any structure to provide void-free dielectric fill.

Tungsten Deposition — Tungsten is used in the contact area of a chip that connects the transistors to the wiring circuitry. In aluminum-based devices, tungsten is also used in the structures that connect the multiple layers of aluminum wiring. Applied has two products for depositing tungsten: the Applied Centura Sprint® Tungsten CVD system and the Applied Centura iSprint ALD/CVD system which provide tungsten filling capability to 20nm and below.

Physical Vapor Deposition

The Applied Endura CuBS (copper barrier/seed) PVD system is widely used by customers for fabricating copper-based chips. Using PVD technology, the system deposits a tantalum-based barrier film that prevents copper material from entering other areas of the device and then a copper seed layer that primes the structure for the subsequent deposition of bulk copper. The Applied Endura CuBS RFX PVD system extends cost-effective CuBS technology to the 22nm node. The Applied Endura Avenir™ RF PVD system sequentially deposits the multiple metal film layers that form the heart of the industry's new, faster, metal gate transistors. The Applied Endura iLB PVD/ALD system advances the state-of-the-art in ALD technology, enabling customers to shrink their speed-critical contact structures for 20nm and below devices. The Applied Endura Amber™ PVD system uses copper reflow technology to achieve rapid, void-free fill of interconnect structures at virtually any device node.

Metrology and Wafer Inspection

Critical Dimension and Defect Review Scanning Electron Microscopes (CD-SEMs and DR-SEMs) — Scanning electron microscopes (SEMs) use an electron beam to form images of microscopic features of a patterned wafer at extremely high magnification. Applied's SEM products provide customers with full automation, along with the high accuracy and sensitivity needed for measuring very small CDs. The Applied VeritySEM® 4i+ metrology system uses proprietary SEM imaging technology to enable precise control of the lithography and etching processes, measuring CDs at a precision of less than 0.3nm. Applied's OPC Check™ software for the VeritySEM system performs automated qualification of OPC-based (optical proximity correction) chip designs, significantly reducing mask verification time over conventional manual methods.

DR-SEMs review defects on the wafer (such as particles, scratches or residues) that are first located by a defect detection system and then classify the defects to identify their source. The high-throughput, fully automatic Applied SEMVision™ Defect Analysis products enable customers to use this technology as an integral part of their production lines to analyze critical defects with industry-leading throughput. In 2013, Applied introduced the latest generation of defect review and classification technology with its Applied SEMVision G6 system, designed to accelerate time-to-yield for leading-edge chip manufacturing at the 1X-nm node and beyond. The system delivers a 30% resolution improvement over the previous SEMVision generation, making it the highest available in the industry.

Mask Making

Applied's Tetra™ line of systems has been used by mask makers worldwide to etch the majority of high-end masks over the last five years. The Applied Centura Tetra EUV (extreme ultraviolet) Advanced Reticle Etch system is an advanced etch tool for fabricating leading-edge masks at 22nm and below. The Applied Aera3™ Mask inspection system also addresses the challenges of detecting defects on 22nm masks, using sophisticated aerial imaging technology that allows users to immediately see how the pattern on the mask will appear on the wafer, revealing only the defects most likely to print and significantly reducing inspection time. These systems also address the challenge of fabricating emerging EUV lithography masks.

Item 1A. *Risk Factors*

Applied must accurately forecast, and allocate appropriate resources and investment towards addressing, key technology changes and inflections, such as the transition to 20nm devices, in order to enable opportunities for gains. In addition, the industry transition from 300mm to 450mm wafers presents opportunities as well as risks and uncertainties, including those related to cost, technical complexity, timing, and the resulting effect on demand for manufacturing equipment and services. Several semiconductor customers have invested in another wafer fabrication equipment supplier to help fund development of 450mm and other new technologies, which may influence the timing of technology transitions, funding allocations or other matters.

Item 7. Management's Discussion and Analysis of Financial Condition and Results of Operations
Research, Development and Engineering

In fiscal 2013, Applied increased its investment in 300mm product development. Applied developed new applications for its epitaxial technology, enabling industry transition to NMOS transistors at the 20nm node and enabling chip makers to build faster devices and deliver next-generation mobile computing power. Applied also released its next-generation defect review and classification technology that delivers industry-leading resolution used for finding, identifying and analyzing defects in 3D FinFET and high aspect ratio structures at 10nm nodes. Applied also continued to invest in the development of 450mm wafer fabrication equipment.

Becton Dickinson

Item 7. Management's Discussion and Analysis of Financial Condition and Results of Operations
Summary of Financial Results
Medical Segment

Medical segment revenue growth was driven by solid growth in all units. Medical Surgical Systems revenue growth was largely attributable to sales in emerging markets and strong international sales of safety-engineered products. Revenue growth in the Diabetes Care unit reflected strong sales of pen needles, including the *BD Ultra-Fine*™ Nano and *BD PentaPoint*™ products, as well as the *BD AutoShield*™ Duo Pen Needle. Revenue growth in the Pharmaceutical Systems unit primarily benefitted from the acquisition of Safety Syringes in the first quarter of fiscal year 2013. Global sales of safety-engineered products were $1.0 billion, compared with $966 million in the prior year, and included an estimated $8 million unfavorable impact due to foreign currency translation. p. 21

Medical segment revenue growth, on a foreign currency-neutral basis, reflected solid growth in all units. Medical Surgical Systems revenue reflected solid growth of international safety-engineered product sales and growth from sales of the *BD PhaSeal™* product resulting from the Carmel Pharma, AB ("Carmel") acquisition that occurred in the fourth quarter of 2011. Diabetes Care revenue growth reflected continued strong sales of pen needles, including sales of the *BD Ultra-Fine™* Nano. Pharmaceutical Systems revenue reflected the continued strong demand from companies producing biotech drugs and certain heparin products. Global sales of safety-engineered products were $966 million, compared with $885 million in 2011, and included an estimated $14 million unfavorable impact due to foreign currency translation.

Broadcom

Item 1. Business
Manufacturing
Wafer Fabrication

Most of our products are manufactured using complementary metal oxide semiconductor, or CMOS, process technology. Our products are currently fabricated on a variety of processes ranging from 500 nanometers to 28 nanometers. We generally evaluate the benefits, on a product-by-product basis, of migrating to smaller geometry process technologies. Approximately 60% of our products are currently manufactured in 65 nanometers (with an increasing number of products being manufactured in 40 nanometers). We are designing most new products in 40 nanometers, 28 nanometers and 20 nanometers, and are beginning to evaluate FinFET technologies. See "*Risk Factors*" under Item 1A of this Report for a discussion of the risks associated with transitioning to smaller geometry process technologies.

Item 1A. *Risk Factors*

We manufacture and sell complex products and may be unable to successfully develop and introduce new products.

We have experienced hardware and software defects and bugs associated with the introduction of our highly complex products. If any of our products contain defects or bugs, or have reliability, quality, security or compatibility problems, our reputation may be damaged and customers may be reluctant to buy our products. These problems could interrupt or delay sales and shipments of our products to customers. To alleviate these problems, we may have to divert our resources from other development efforts. In addition, these problems could result in claims against us by our customers or others, including possible claims for consequential damages and/or lost profits. As we transition to manufacturing our products in smaller geometry processes, such as 28 nanometers and below, these risks are enhanced.

We depend on third parties to fabricate, assemble and test our products.

As a fabless semiconductor company, we do not own or operate fabrication, assembly or test facilities. We rely on third parties to manufacture, assemble and test substantially all of our semiconductor devices. Accordingly, we cannot directly control our product delivery schedules and quality assurance. This lack of control could result in product shortages or quality assurance problems. These issues could delay shipments of our products or increase our assembly or testing costs. In addition, the consolidation of foundry subcontractors, as well as the increasing capital intensity and complexity associated with fabrication in smaller process geometries has limited our diversity of suppliers and increased our risk of a "single point of failure." Specifically, as we move to smaller geometries, we have become increasingly reliant on TSMC for the manufacture of product at and below 40 nanometers. The lack of diversity of suppliers could also drive increased wafer prices, adversely affect our results of operations, including our product gross margins.

Item 7. Management's Discussion and Analysis of Financial Condition and Results of Operations
Research and Development Expense

The increase in 2012 salaries and benefits was primarily attributable to an increase in headcount of approximately 1,450personnel, bringing headcount to over 8,700 at December 31, 2012, which represents a 20.0% increase from our December 31, 2011 levels. Approximately 40% of the increase in headcount was the result of our acquisitions of NetLogic and BroadLight. See below for discussion of stock-based compensation. Development and design costs increased in 2012 due to increases in prototyping costs, engineering design tool expenses and licensing fees. The increase in 2011 salaries and benefits and stock-based compensation were primarily attributable to an increase in headcount of approximately 450 personnel, bringing headcount to approximately 7,250 at December 31, 2011, which represents a 6.6% increase from our December 31, 2010 levels. Development and design costs vary from period to period depending on the timing development and tape-out of various products. As we transition to 40 nanometers and 28 nanometers products, tape-out costs could increase.

We remain committed to significant research and development efforts to extend our technology leadership in the wired and wireless communications markets in which we operate. We expect research and development costs to increase as a result of growth in, and the diversification of, the markets we serve, new product opportunities, the number of design wins that go into production, changes in our compensation policies, and any expansion into new markets and technologies, including acquisitions. Approximately 60% of our products are currently manufactured in 65 nanometers (with an increasing number of products being manufactured in 40 nanometers). We are designing most new products in 40 nanometers, 28 nanometers and 20 nanometers and are beginning to evaluate FinFET technologies. We currently hold more than 7,800 U.S. and more than 3,100 foreign patents and more than 7,700 additional U.S. and foreign pending patent applications. We maintain an active program of filing for and acquiring additional U.S. and foreign patents in wired and wireless communications and other fields.

Cameron International

Item 1. Business
New Product Development

During 2012, Cameron funded university research along with research at a private spin-off business named NanoMech resulting in the creation of TriboTuff® lubricant, a macro-molecular-manufactured solution which reduces mechanical friction to near zero improving the performance of machinery and critical oilfield components.

Carefusion

Item 10. Directors, Executive Officers and Corporate Governance
Executive Officers of the Registrant

Mr. Gallahue is the Chairman of our Board of Directors and Chief Executive Officer. Prior to joining us in January 2011, he was the president, chief executive officer and a director of ResMed Inc., a medical device firm serving the sleep disordered breathing and respiratory markets. Mr. Gallahue joined ResMed in January 2003 as president and chief operating officer of the Americas and was promoted to ResMed's president in September 2004. He served in that role until he was named president, chief executive officer and a director of ResMed in January 2008. Prior to joining ResMed, from January 1998 to December 2002, he held positions of increasing responsibility at Nanogen, Inc., a DNA research and medical diagnostics company, including president and chief financial officer. Prior to 1998, Mr. Gallahue held various marketing, sales and financial positions within Instrumentation Laboratory, The Procter & Gamble Company and General Electric Company. He is a director of Volcano Corporation. During the prior five years, Mr. Gallahue also served on the board of directors of ResMed.

Dow Chemical

Item 1. Business
Performance Monomers

Coatings and Infrastructure Solutions' businesses each serve one or more key market segments, as noted below:

Business:

Dow Water and Process Solutions

Major Products:

DOW ADSORBSIA™ selective media, DOW EDI™ modules, DOWEX™ and AMBERJET™ ion exchange resins, DOWEX™ OPTIPORE™ polymeric adsorbent resins, DOW FILMTEC™ reverse osmosis and nanofiltration elements, TEQUATIC™ PLUS fine particle filter AMBERLYST™ polymeric catalysts

Applications/Market Segments:

Providing the right, cost effective separation technology for water treatment and filtration; energy (power, oil and gas); pharmaceutical; food and beverage; chemical processing

Intel

Item 1. Business
Products and Product Strategy by Operating Segment

Our ***PC Client Group*** operating segment offers products that are incorporated in notebook (including Ultrabook, detachable, and convertible systems) and desktop computers for consumers and businesses. In 2012 we introduced the 3rd generation Intel® Core™ processor family for use in notebook and desktop computers. These processors use 22-nanometer (nm) transistors and our Tri-Gate transistor processor technology. Our Tri-Gate transistor technology extends Moore's Law and is the world's first 3-D Tri-Gate transistor on a production technology. These enhancements in combination can provide significant power savings and performance gains when compared to previous-generation technologies.

Our ***Data Center Group*** operating segment offers products designed to provide leading performance, energy efficiency, and virtualization technology for server, workstation, and storage platforms. We are also increasing our focus on products designed for high-performance computing, mission-critical computing, and cloud computing services. The cloud computing market segment refers to servers and other products that enable on-demand network access to a shared pool of configurable software, services, and computing devices. Such products include the introduction in 2012 of our many-core Intel® Xeon Phi™coprocessor with 60 or more high-performance, low-power Intel processor cores, as well as our server platform that incorporates our 32nm Intel® Xeon®processors supporting as many as 10 cores for server platforms. The Intel Xeon Phi coprocessors are positioned to boost the power of the world's most advanced supercomputers, allowing for trillions of calculations per second, while the 32nm Intel Xeon processors provide faster throughput for cloud computing-based services. In the data storage market segment, we introduced 64-bit Intel Atom microarchitecture-based SoC solutions to focus on the emerging market for highly dense, low-power server configurations. These products allow server rack space optimization and reduced energy costs with microservers that require less than 10 watts per server node.

Manufacturing and Assembly and Test

As of December 29, 2012, most of our microprocessors were manufactured on 300mm wafers using our 22nm and 32nm process technology. As we move to each succeeding generation of manufacturing process technology, we incur significant start-up costs to prepare each factory for manufacturing. However, continuing to advance our process technology provides benefits that we believe justify these costs. The benefits of moving to each succeeding generation of manufacturing process technology can include using less space per transistor, reducing heat output from each transistor, and increasing the number of integrated features on each chip. These advancements can result in microprocessors that are higher performing, consume less power, and cost less to manufacture. In addition, with each shift to a new process technology, we are able to produce more microprocessors per square foot of our wafer fabrication facilities. The costs to develop our process technology are significantly less than adding capacity by building additional wafer fabrication facilities using older process technology.

Our NAND flash memory products are manufactured by IMFT and Micron Technology, Inc. using 20nm, 25nm, or 34nm process technology, and assembly and test of these products is performed by Micron and other external subcontractors. For further information, see "Note 10: Equity Method and Cost Method Investments" in Part II, Item 8 of this Form 10-K.

Research and Development

As part of our R&D efforts, we plan to introduce a new microarchitecture for our notebook, Ultrabook system, and Intel Xeon processors approximately every two years and ramp the next generation of silicon process technology in the intervening years. We refer to this as our "tick-tock" technology development cadence as subsequently illustrated. In 2012, we started manufacturing products with our 4th generation Intel® Core™ microarchitecture, a new microarchitecture using our existing 22nm three-dimensional Tri-Gate transistor process technology (22nm process technology). We are currently developing 14nm process technology, our next-generation process technology, and expect to begin manufacturing products using that technology in 2013. Our leadership in silicon technology has enabled us to make Moore's Law a reality.

Our leadership in silicon technology has also helped expand on the advances anticipated by Moore's Law by bringing new capabilities into silicon and producing new products optimized for a wider variety of applications. We have accelerated the Intel Atom processor-based SoC roadmap for smartphones, tablets, and other devices, from 32nm through 22nm to 14nm. We intend that Intel Atom processors will eventually be on the same process technology as our leading-edge products for both smartphones and tablets. We expect that this acceleration will result in a significant reduction in transistor leakage, lower active power, and an increase in transistor density to enable more powerful smartphones and tablets with more features and longer battery life.

Item 7. Management's Discussion and Analysis of Financial Condition and Results of Operations
Overview

Our fourth quarter revenue of $13.5 billion was flat from the third quarter of 2012. Historically, our revenue generally has increased in the fourth quarter. However, softness in PC demand and continued decline of inventory in the PC supply chain as OEMs reduce inventory on older-generation products negatively impacted our results for the fourth quarter. The decline in our gross margin percentage in the fourth quarter was driven by excess capacity charges as we responded to lower demand by bringing down inventory levels and redirecting capital resources to our 14nm process technology. Our gross margin was also negatively impacted by higher inventory reserves on production of our next-generation microarchitecture products, code-named Haswell, which we expect to qualify for sale in the first quarter of 2013.

During 2012 we made significant product introductions across all our businesses, including PC client, servers, smartphones and tablets, and extended our manufacturing and process technology leadership. We launched our next-generation server-based products, the Intel Xeon processor E5 family, which provides higher performance and better energy-efficiency than prior-generation products. In 2012 we continued to extend our process technology leadership with the introduction of our 22nm process technology products that utilize three-dimensional Tri-Gate transistor technology. These products also improve performance and energy efficiency compared to prior generation products and helped us accelerate our Ultrabook strategy. In 2012 we entered the smartphone market segment with six mobile phone providers launching the first Intel architecture-based smartphones. We are also expanding in the tablet market segment with designs based on Android* and Windows* operating systems currently shipping.

As we look into 2013, we expect revenue to grow in the low single digits with particular strength in our server market segment. We believe the renewed innovation in the PC industry that we fostered with Ultrabook systems and expanded to other thin and light form factors, will blur the lines between tablets and notebooks and provide growth opportunities in 2013. We also expect to launch new SoCs for smartphones and tablets, based on our 22nm process technology. In 2013, we expect an increase in capital expenditures primarily driven by beginning construction of a 450mm development facility as we progress toward manufacturing with 450mm wafer technology later in the decade.

Results of Operations

Our overall gross margin dollars for 2012 decreased by $606 million, or 2%, compared to 2011. The decrease was due in large part to approximately $490 million of excess capacity charges, as well as lower PC Client Group and Data Center Group platform revenue. To a lesser extent, higher PC Client Group and Data Center Group platform unit costs as well as lower netbook and IMC revenue contributed to the decrease. The decrease was partially offset by approximately $645 million of lower start-up costs as we transition from our 22nm process technology to R&D of our next-generation 14nm process technology, as well as $422 million of charges recorded in 2011 to repair and replace materials and systems impacted by a design issue related to our Intel 6 Series Express Chipset family. The decrease was also partially offset by the two additional months of results from our acquisition of McAfee, which occurred on February 28, 2011, contributing approximately $334 million of additional gross margin dollars in 2012 compared to 2011. The amortization of acquisition-related intangibles resulted in a $557 million eduction to our overall gross margin dollars in 2012, compared to $482 million in 2011, primarily due to acquisitions completed in the first quarter of 2011.

PC Client Group

Operating income decreased by $1.7 billion, or 12%, in 2012 compared to 2011 driven by $649 million of lower gross margin and $1.1 billion of higher operating expenses. The decrease in gross margin was primarily due to lower platform revenue. Additionally, approximately $455 million of higher excess capacity charges and higher platform unit costs contributed to the decrease. These decreases were partially offset by approximately $785 million of lower start-up costs as we transition from manufacturing start-up costs related to our 22nm process technology to R&D of our next-generation 14nm process technology. Additionally, the first half of 2011 included $422 million of charges recorded to repair and replace materials and systems impacted by a design issue related to our Intel 6 Series Express Chipset family.

Operating income increased by $1.8 billion in 2011 compared to 2010 as the gross margin increase of $2.4 billion was partially offset by $584 million of higher operating expenses. The increase in gross margin was primarily due to higher platform revenue partially offset by approximately $960 million of higher start-up costs as we transitioned into production using our 22nm process technology. Higher platform unit costs and inventory write-offs as compared to 2010 also contributed to the offset.

Operating Expenses

Research and Development. R&D spending increased by $1.8 billion, or 22%, in 2012 compared to 2011, and increased by $1.8 billion, or 27%, in 2011 compared to 2010. The increase in 2012 compared to 2011 was driven by increased investments in our products for smartphones, tablets, Ultrabook systems, and data centers. Additionally, R&D spending increased due to higher process development costs for our next-generation 14nm process technology, higher compensation expenses mainly due to annual salary increases, the full first quarter expenses of IMC and McAfee in 2012 (both acquired in the first quarter of 2011), and higher costs related to the development of 450mm wafer technology. The increase in 2011 compared to 2010 was primarily due to the expenses of McAfee and IMC, and to higher compensation expenses based on an increase in the number of employees. In addition, lower overall process development costs due to the transition to manufacturing start-up costs related to our 22nm process technology were mostly offset by higher process development costs due to R&D of our next-generation 14nm process technology.

Investing Activities

Cash used for investing activities decreased slightly in 2011 compared to 2010. A decrease due to net maturities and sales of available-for-sale investments in 2011 as compared to net purchases of available-for-sale investments in 2010 was offset by higher cash paid for acquisitions, of which the substantial majority was for our acquisition of McAfee in the first quarter of 2011, and an increase in capital expenditures. The significant increase in capital expenditures in 2011 compared to 2010 was due to the expansion of our network of fabrication facilities to include an additional large-scale fabrication facility, as well as bringing our 22nm process technology manufacturing capacity online.

International Business Machines

Item 1. Business:
Research, Development and Intellectual Property

IBM Research works with clients and the company's business units through 12 global labs on near-term and mid-term innovations. It contributes many new technologies to IBM's portfolio every year and helps clients address their most difficult challenges. IBM Research also explores the boundaries of science and technology—from nanotechnology, to future systems, to big data analytics, to secure clouds, to IBM Watson, a "cognitive" learning system that applied advanced analytics to defeat the all-time champions on the television quiz show, *Jeopardy!*. The Watson system has been introduced to the market for advanced healthcare applications and is being further developed and extended within healthcare and in other industries.

Jacobs Engineering Group

Item 1. Business
The Industries and Markets in Which Our Clients Operate
Buildings

Advanced technology clients require highly specialized buildings in the fields of medical research, nano science, biotechnology, and laser sciences. We offer total integrated design and construction management solutions to these projects, many of which are world leaders in their functions.

Industrial and Other
High-Technology Manufacturing

We provide our core services for a variety of high tech manufacturing and test facilities, particularly for clients in the automotive and industrial industries. Typical automotive projects range from conceptual design and feasibility studies to complete design-build programs of aero-acoustic wind tunnels, engine test facilities, acoustic enclosures, transmission test stands; powertrain, environmental, emissions, altitude, and electromagnetic compatibility test facilities; in-line and end-of-line component test stands; and computer-based measurement and control systems. We also serve advanced technology and research facilities, including facilities supporting research in fusion and fission energy, nanoscale materials, and high-powered lasers and X-rays to support important research activities in the U.S., Europe, and the U.K.

JDS Uniphase

Item 1. Business
Business Segments
Offerings

Industry-leading innovation led to the STB, which integrates all major optical transport functions (wavelength switching, preamplification, postamplification, and monitoring) into a single-slot blade. This all-in-one solution reduces the size, cost, and power requirements of optical components, incorporates nano wavelength selective switch technology, and enables greater chassis density and a smaller footprint.

Optical Security and Performance Products
Offerings

Custom Optics: Optical thin-film coatings are submicroscopic (nanometer to micrometer) layers of materials, such as silicon or magnesium fluoride, that are applied to the surface of a substrate, including glass, plastic or metal. Thin-film coatings control the behavior of light to produce effects such as reflection, refraction, absorption, abrasion resistance, antiglare, oxygen and/or moisture transmission, and electrical conductivity for a variety of applications.

KLA-Tencor

Item 1. Business
The Company

KLA-Tencor Corporation ("KLA-Tencor" or the "Company" and also referred to as "we" or "our") is a leading supplier of process control and yield management solutions for the semiconductor and related nanoelectronics industries. Our products are also used in a number of other high technology industries, including the light emitting diode ("LED") and data storage industries, as well as general materials research.

Industry
Current Trends

The rapid growth of consumer demand for mobile devices, including smartphones, tablets and portable PCs, is currently driving the electronics industry and, as a result, the semiconductor industry as well. Contained within each of these latest consumer devices are advanced semiconductors that are helping enable the features consumers want in device performance, such as battery management and speed, at a lower cost. Alongside this market growth, the industry continues to witness a high rate of change in technology, with the emergence of new techniques and architectures in production today, such as three-dimensional ("3-D") transistors, advanced patterning lithography and semiconductors with critical dimensions at 28 nanometer and below. KLA-Tencor's inspection and measurement technologies play a key role in enabling the success of our customers' advanced semiconductor manufacturing processes.

Products

KLA-Tencor is engaged primarily in the design, manufacture and marketing of process control and yield management solutions for the semiconductor and related nanoelectronics industries and provide a comprehensive portfolio of defect inspection and metrology products, and related service, software and other offerings.

Chip Manufacturing
Patterned Wafer Inspection

NanoPoint™ for the 2900 Series broadband optical wafer defect inspectors is a family of technologies that enables the rapid discovery and high sensitivity monitoring of yield-critical defects by leveraging critical patterns on the system. NanoPoint can indicate the need for mask re-design within hours, potentially accelerating the identification and resolution of design issues from months to days

Wafer Manufacturing

Our wafer inspection portfolio is anchored by the Surfscan SP3 Series and includes the Surfscan SP3 450 launched in July 2012 to support early 450mm development activity at substrate and process tool manufacturers. The Surfscan SP3 Series and the Surfscan SP2 Series are defect inspection systems designed to enable development and production monitoring of polished wafers, epi wafers and engineered substrates. The SURFmonitor module characterizes wafer surface quality and captures the low-contrast defects. The WaferSight™ platform offers bare wafer geometry and nanotopography metrology capabilities. Other products that we offer for the wafer manufacturing market are highlighted in the product table at the conclusion of this "Products" section.

General Purpose/Lab Applications

A range of industries, including general scientific and materials research and optoelectronics, require measurements of surface topography to either control their processes or research new material characteristics. Typical measurement parameters that our tools address include flatness, roughness, curvature, peak-to-valley, asperity, waviness, texture, volume, sphericity, slope, density, stress, bearing ratio and distance (mainly in the micron to nanometer range).

Item 7. Management's Discussion and Analysis of Financial Condition and Results of Operations
Executive Summary

KLA-Tencor Corporation is a leading supplier of process control and yield management solutions for the semiconductor and related nanoelectronics industries. Our broad portfolio of defect inspection and metrology products, and related service, software and other offerings, primarily supports integrated circuit ("IC" or "chip") manufacturers throughout the entire semiconductor fabrication process, from research and development to final volume production. We provide leading-edge equipment, software and support that enable IC manufacturers to identify, resolve and manage significant advanced technology manufacturing process challenges and obtain higher finished product yields at lower overall cost. In addition to serving the semiconductor industry, we also provide a range of technology solutions to a number of other high technology industries, including the light emitting diode ("LED") and data storage industries, as well as general materials research.

Our products and services are used by the vast majority of bare wafer, IC, lithography reticle ("reticle" or "mask") and disk manufacturers around the world. Our products, services and expertise are used by our customers to measure and control nanometric-level manufacturing processes, and to detect, analyze and resolve critical product defects that arise in that environment. Our revenues are driven largely by our customers' spending on capital equipment and related maintenance services necessary to support key transitions in their underlying product technologies, or to increase their production volumes in response to market demand. Our semiconductor customers generally operate in one or more of the three major semiconductor markets -- memory, foundry and logic. All three of these markets are characterized by rapid technological changes and sudden shifts in end-user demand, which influence the level and pattern of our customers' spending on our products and services. Although capital spending in all three semiconductor markets has historically been very cyclical, the demand for more advanced and lower cost chips used in a growing number of consumer electronics, communications, data processing, and industrial and automotive products has resulted over the long term in a favorable demand environment for our process control and yield management solutions.

Lam Research

Item 1. Business
Thin Film Deposition

In leading-edge semiconductor designs, metal deposition processes face significant scaling and integration challenges. For advanced copper interconnect structures, challenges for electrochemical deposition ("ECD") include providing complete, void-free fill of HAR structures with low defectivity and high productivity. Electroplating of copper and other metals is also used for TSV and WLP applications, such as forming conductive bumps and redistribution layers ("RDLs"). These applications require excellent within-wafer uniformity at high plating rates, minimizing defects, and reducing costs. For tungsten chemical vapor deposition ("CVD") processes, key requirements are minimizing contact resistance to meet lower power consumption requirements and achieving void-free fill for narrow nanoscale structures. In addition, good barrier step coverage at reduced thicknesses relative to physical vapor deposition/CVD barrier films is also needed to improve contact fill and reduce resistivity.

Linear Technology

Item 1: Business
Products and Markets

Market: Computer/High-End Consumer
Example Product Families: Nano current voltage supervisors

Executive Officers of the Registrant

Mr. McCann was named Chief Operating Officer of Linear Technology in January 2005, prior to that Mr. McCann served as Vice President of Operations since January 2004. Prior to joining the Company, he was Vice President of Operations at NanoOpto Corporation in Somerset, NJ from July 2002 to December 2003, Vice President of Worldwide Operations at Anadigics Inc. in Warren, NJ from December 1998 to June 2002 and held various management positions at National Semiconductor UK Ltd. from August 1985 to September 1998. Mr. McCann received a B.S. (equivalent) in Electrical and Electronic Engineering in 1985 from James Watt College and an MBA in 1998 from the University of Glasgow Business School.

Item 10. Directors, Executive Officers and Corporate Governance

The information required by this item for the Company's directors is incorporated herein by reference to the 2013 Proxy Statement, under the caption "Proposal One - Election of Directors," and for the executive officers of the Company, the information is included in Part I hereof under the caption "Executive Officers of the Registrant."

Newell Rubbermaid

Item 7. Management's Discussion and Analysis of Financial Condition and Results of Operations
Market and Performance Overview

- Supported the launch of the Rubbermaid® Clean & Dry Plunger with NeverWet™ nanotech coating, which forms a shield that repels water, Rubbermaid® Bathroom Scrubbers with four tools to choose from, and Rubbermaid® LunchBlox™ – a collection of customizable, modular food storage containers that snap together to save space and stay organized in lunch bags.

Nvidia

Item 1A: ***Risk Factors***

We depend on foundries to manufacture our products and these third parties may not be able to obtain or successfully implement high quality, leading-edge process technologies or otherwise satisfy our manufacturing requirements, which would harm our business.

We have experienced difficulty in migrating to new manufacturing processes in the past and, consequently, have suffered reduced yields, delays in product deliveries and increased expense levels. For example, due to capacity constraints at TSMC of our 28 nanometer Kepler GPUs in the first quarter of fiscal year 2013, we were unable to fulfill customer demand for our high-end desktop GPU products, and as our sales mix shifted to our mainstream desktop GPU products, revenue and gross margins for the first quarter of fiscal year 2013 were negatively impacted compared to the prior quarter. We experienced continued 28 nanometer-supply constraints in the second quarter of fiscal year 2013.

Item 7. Management's Discussion and Analysis of Financial Condition and Results of Operations
Gross Profit and Gross Margin
Fiscal Year 2013 vs. Fiscal Year 2012

GPU Business. The gross margin of our GPU business increased during fiscal year 2013 when compared to fiscal year 2012. This was primarily due to a richer product mix of our Kepler-based high-end 28 nanometer GeForce desktop products and our Quadro products. Memory margins strengthened on improved market pricing. These favorable contributors to gross margin were primarily offset by higher net inventory reserves in fiscal year 2013 compared to fiscal year 2012.

Pentair

Item 8: Financial Statements and Supplementary Data
Pentair Ltd. and Subsidiaries
Notes to consolidated financial statements

4. Other Acquisitions
Other material acquisitions

In May 2011, we acquired, as part of Water & Fluid Solutions, the Clean Process Technologies (“CPT”) division of privately held Norit Holding B.V. for $715.3 million (€502.7 million translated at the May 12, 2011 exchange rate). CPT’s results of operations have been included in our consolidated financial statements since the date of acquisition. CPT is a global leader in membrane solutions and clean process technologies in the high growth water and beverage filtration and separation segments. CPT provides sustainable purification systems and solutions for desalination, water reuse, industrial applications and beverage segments that effectively address the increasing challenges of clean water scarcity, rising energy costs and pollution. CPT’s product offerings include innovative ultrafiltration and nanofiltration membrane technologies, aseptic valves, CO_2 recovery and control systems and specialty pumping equipment. Based in the Netherlands, CPT has broad sales diversity with the majority of revenues generated in European Union and Asia-Pacific countries.

Qualcomm

Item 7. Management’s Discussion and Analysis of Financial Condition and Results of Operations
Our Segment Results (in millions)
QCT Segment

QCT EBT as a percentage of revenues remained flat in fiscal 2013 as compared to fiscal 2012. During fiscal 2013, QCT revenues increased 38% relative to a combined increase of 26% in research and development expenses and selling, general and administrative expenses, partially offset by a decrease in gross margin percentage. The decrease in QCT EBT as a percentage of revenues in fiscal 2012 was primarily due to a decrease in gross margin percentage, partially offset by an increase of 37% in QCT revenues relative to a combined increase of 33% in research and development expenses and selling, general and administrative expenses. QCT gross margin percentage decreased in fiscal 2013 as a result of the net effects of lower average selling prices and unfavorable product mix, partially offset by a decrease in average unit costs. QCT gross margin percentage decreased in fiscal 2012 as a result of the net effects of lower average selling prices, unfavorable product mix and higher product support costs, partially offset by a decrease in average unit costs. The higher product support costs in fiscal 2012 primarily related to increased expenses incurred to facilitate additional supply of 28 nanometer integrated circuits.

Sandisk

Item 1A. ***Risk Factors***

Our operating results may fluctuate significantly, which may harm our financial condition and our stock price. Our quarterly and annual operating results have fluctuated significantly in the past and we expect that they will continue to fluctuate in the future. Our results of operations are subject to fluctuations and other risks, including, among others:

- inability to develop, or unexpected difficulties or delays in developing or ramping with acceptable yields, new technologies such as 1Y-nanometer or subsequent process technologies, X3 NAND memory architecture, BiCS technology, 3D ReRAM, or other advanced alternative technologies

If we are unable to reduce our manufacturing costs to keep pace with reductions in average selling prices, our gross margins may be harmed. Because of the historical and expected future declines in the price of NAND flash memory, we need to reduce our manufacturing costs in order to maintain adequate gross margins. Our ability to reduce our cost per gigabyte of memory produced depends on technology transitions and the improvement of manufacturing efficiency, including manufacturing yields. If our technology transitions (for example, the production ramp of NAND technology on the 1Y-nanometer process node) take longer or are more costly to complete than anticipated, our manufacturing costs may not remain competitive with other flash memory producers, which would harm our gross margins and financial results. Furthermore, the inherent physical technology limitations of NAND flash technology may result in more costly technology transitions that we have experienced in the past, which could further limit our ability to keep pace with reductions in average selling prices. Manufacturing yields are a function of both design and manufacturing process technology, and yields may also be impacted by equipment malfunctions, fabrication facility accidents or human error. Yield problems may not be identified during the production process or solved until an actual product is manufactured and tested, further increasing our costs. If we are unable to improve manufacturing yields or other manufacturing efficiencies, our gross margins and results of operations would be harmed.

In transitioning to new technologies and products, we may not achieve OEM design wins, our OEM customers may delay transition to new technologies, our competitors may transition more quickly than we do, or we may experience product delays, cost overruns or performance issues that could harm our business. The transition to new generations of products, such as products containing 19-nanometer, 1Y-nanometer or subsequent process technologies and/or X3 NAND memory architecture, is highly complex and requires new controllers, new test procedures and modifications to numerous aspects of our manufacturing processes, resulting in the need for extensive qualification of the new products by our OEM customers and us. If we fail to achieve OEM design wins with new technologies such as 19-nanometer, 1Y-nanometer or the use of X3 in certain products, or if our OEM customers choose to transition to these new technologies more slowly than our roadmap plans, we may be unable to achieve the cost structure required to support our profit objectives or may be unable to grow or maintain our OEM market share. Furthermore, there can be no assurance that technology transitions will occur on schedule, at the yields or costs that we anticipate, or that products based on the new technologies will meet customer specifications. Any material delay in a development or qualification schedule could delay deliveries and harm our operating results. If our competitors transition to these new technologies more quickly than we are able to, our ability to compete effectively would be harmed.

Item 7. Management's Discussion and Analysis of Financial Condition and Results of Operations
General

We believe the markets for flash storage are generally price elastic, meaning that a decrease in the price per gigabyte results in increased demand for higher capacities and the emergence of new applications for flash storage. We strive to continuously reduce the cost of NAND flash memory in order to enable us to profitably grow our business, supply a diverse set of customers and channels, and continue to grow our markets. A key component of our ability to reduce the cost of NAND flash memory is our ability to continue to transition our NAND flash memory process technology to smaller nodes. We currently expect to be able to continue to scale our NAND flash memory through a few additional generations, but beyond that there is no certainty that further technology scaling can be achieved cost-effectively with the current NAND flash memory architecture. We continue to invest in future generations of NAND flash memory, and we are also pursuing alternative technologies, such as BiCS and 3D ReRAM technologies, which we believe may be a viable alternative to NAND flash memory when NAND flash memory can no longer cost-effectively scale at a sufficient rate, or at all. We believe BiCS technology, if successful, could enable further memory cost reductions beyond the NAND roadmap. However, even when NAND flash memory can no longer scale further, we expect NAND flash memory and potential alternative technologies to coexist for an extended period of time. Currently, we are focused on transitioning our products to 19-nanometer and 1Y-nanometer technologies and improving manufacturing efficiencies.

Gross Profit and Margins

Product gross margins decreased in fiscal year 2012, compared to fiscal year 2011, due primarily to declines in average selling price per gigabyte of (45%) exceeding cost reduction per gigabyte of (36%). The degree to which price decline exceeded cost decline was primarily due to oversupply in the NAND industry in the first half of fiscal year 2012. Costs per gigabyte improved over the prior year primarily due to wafer production transitioning from 24-nanometer to 19-nanometer and lower usage of non-captive memory. This cost reduction includes higher inventory-related charges in fiscal year 2012, offset by a reduction in fab start-up costs that occurred in fiscal year 2011 and did not recur in fiscal year 2012.

Product gross margins decreased in fiscal year 2011, compared to fiscal year 2010, due primarily to average selling price reductions exceeding cost reductions. Costs per gigabyte decreased over the prior year by 30%, primarily due to wafer production transitioning from 32-nanometer to 24-nanometer. This cost reduction includes the negative impact of the appreciation of the Japanese yen to the U.S. dollar for wafer purchases denominated in Japanese yen, increased sale of products incorporating non-captive flash memory, startup costs incurred by Flash Forward, a ($25) million charge related to both a power outage in early March 2011 and an earthquake on March 11, 2011, that affected Flash Ventures, and an increase in amortization of acquisition-related intangible assets related to our acquisition of Pliant Technology, Inc., or Pliant.

Waters

Item 1: Business Description
TA Division
Thermal Analysis, Rheometry and Calorimetry

Thermal analysis and rheometry instruments are heavily used in material testing laboratories and, in many cases, provide information useful in predicting the suitability of fine chemicals, polymers and viscous liquids for various industrial, consumer goods and healthcare products, as well as for life science research. As with systems offered through the Waters Division, a range of instrument configurations is available with increasing levels of sample handling and information processing automation. In addition, systems and accompanying software packages can be tailored for specific applications. For example, the Q-Series™ family of differential scanning calorimeters includes a range of instruments, from basic dedicated analyzers to more expensive systems that can accommodate robotic sample handlers and a variety of sample cells and temperature control features for analyzing a broad range of materials. In 2010, TA introduced the Nano ITC Low Volume system, which is engineered to provide isothermal titration calorimetry capabilities for applications with limited sample sizes. Also in 2010, TA introduced the DMA-RH Accessory, which is designed to be used with the Q800 Dynamic Mechanical Analyzer to allow the mechanical properties of a sample to be analyzed under controlled and/or varying conditions of both relative humidity and temperature. In 2011, TA introduced the Discovery DSC, Discovery TGA and Discovery Hybrid Rheometer, which provide unmatched measurement performance in the fields of differential scanning calorimetry and rheometry.

Xilinx

Item 1. Business
Silicon Product Overview

28-nanometer (nm) Product Families

The 7 series devices that comprise our 28-nm product families are fabricated on a high-K metal gate, high performance, low power 28-nm process technology. These devices are based on a scalable and optimized architecture, which enables design, IP portability and re-use across all families as well as provides designers the ability to achieve the appropriate combination of I/O support, performance, feature quantities, packaging and power consumption to address a wide range of applications.

The Zynq-7000 family is the first family of Xilinx programmable SoCs. This new class of product combines an industry-standard ARM dual-core Cortex™-A9 MPCore™ processing system with Xilinx 28-nm architecture. There are five devices in the Zynq-7000 SoC family that allow designers to target cost sensitive as well as high-performance applications from a single platform using industry-standard tools. These devices are designed to enable incremental market opportunities in applications such as industrial motor control, driver assistance and smart surveillance systems, and smart heterogeneous wireless networks.

40-nm and 45-nm Product Families

The Virtex-6 FPGA family consists of 13 devices and is the sixth generation in the Virtex series of FPGAs. Virtex-6 FPGAs are fabricated on a high-performance, 40-nm process technology. There are three Virtex-6 families, and each is optimized to deliver different feature mixes to address a variety of markets…

The latest generation in the Spartan FPGA series, the Spartan-6 FPGA family, is fabricated on a low-power 45-nm process technology. The Spartan-6 family is the PLD industry's first 45-nm high-volume FPGA family, consisting of 11 devices in two product families:

65-nm Product Families

The Virtex-5 FPGA family consists of 26 devices in five product families: Virtex-5 LX FPGAs for logic-intensive designs, Virtex-5 LXT FPGAs for high-performance logic with serial connectivity, Virtex-5 SXT FPGAs for high-performance DSP with serial connectivity, Virtex-5 FXT FPGAs for embedded processing with serial connectivity and Virtex-5 TXT FPGAs for high-bandwidth serial connectivity.

Other Product Families

Prior generation Virtex families include Virtex-4, Virtex-II Pro, Virtex-II, Virtex-E and the original Virtex family. Spartan family FPGAs include 90-nm Spartan-3 FPGAs, the Spartan-3E family and the Spartan-3A family. Prior generation Spartan families include Spartan-IIE, Spartan-II, Spartan XL and the original Spartan family.

Research and Development

Our research and development (R&D) activities are primarily directed toward the design of new ICs, the development of new software design automation tools for hardware and embedded software, the design of logic IP, the adoption of advanced semiconductor manufacturing processes for ongoing cost reductions, performance and signal integrity improvements and lowering PLD power consumption. As a result of our R&D efforts, we have introduced a number of new products during the past several years including the Virtex-7, Kintex-7, Artix-7 and Zynq-7000 families. We have made enhancements to our IP core offerings and introduced Vivado tools, our next generation software design suite. We extended our collaboration with our foundry suppliers in the development of 65-nm, 45-nm, 40-nm and 28-nm manufacturing technology, enabling us to be the first company in the PLD industry to ship 45-nm high-volume as well as 28-nm FPGA devices. Additionally, our investment in R&D has allowed us to ship the industry's first 28-nm PLD with embedded ARM technology as well as the industry's first 3D IC devices.

Item 1A. ***Risk Factors***

Our success depends on our ability to develop and introduce new products and failure to do so would have a material adverse impact on our financial condition and results of operations.

Our success depends in large part on our ability to develop and introduce new products that address customer requirements and compete effectively on the basis of price, density, functionality, power consumption and performance. The success of new product introductions is dependent upon several factors, including:

- ability to utilize advanced manufacturing process technologies on circuit geometries of 28-nm and smaller.

Item 7. Management's Discussion and Analysis of Financial Condition and Results of Operations
Research and Development

R&D spending increased $40.2 million, or 9%, during fiscal 2013, and $42.8 million, or 11%, during fiscal 2012, compared to the same periods last year. The increases for both periods were primarily attributable to higher employee-related expenses (including stock-based compensation expense), and mask and wafer expenses related to our 28-nm development activities. R&D for fiscal 2013 also included spending for next generation products.

Zoetis

Item 10. Directors, Executive Officers and Corporate Governance

Gregory Norden has served as a member of our board since January 2013. Mr. Norden is the Managing Director of G9 Capital Group LLC which invests in early stage ventures and provides corporate finance advisory services. From 1989 to 2010, Mr. Norden held various senior positions with Wyeth/American Home Products, most recently as Wyeth's Senior Vice President and Chief Financial Officer (from 2007 to 2010). Prior to this role, Mr. Norden was Executive Vice President and Chief Financial Officer of Wyeth Pharmaceuticals. Prior to his affiliation with Wyeth, Mr. Norden served as Audit Manager at Arthur Andersen & Co. Mr. Norden also serves on the Board of Directors of Welch Allyn, a provider of medical diagnostic equipment, and NanoString Technologies, a provider of life science tools for translational research and development of molecular diagnostic products. Mr. Norden is a former director of Human Genome Sciences, Inc., where he served until 2012.

Appendix B

Excerpts from S&P 500 Companies' Corporate Social Responsibility or Sustainability Reports or Websites

(Nano references highlighted in yellow)
Si2 reviewed reports and websites in 4th quarter 2013

Air Products & Chemicals

Citizens of the World

In April 2012, Air Products acquired DuPont's interest in DuPont Air Products NanoMaterials LLC, strengthening our position in the high-growth global semiconductor and wafer polishing markets.

Trends Shaping Our World

Technology advancements are occurring at an exponential rate. Information technology is now a vital, multidimensional part of our daily lives. Fields such as biotechnology and nanotechnology represent the next frontiers of global economic development. Technology will enable faster innovation, and the barriers to enter markets will be lowered.

Source: *2013 Sustainability Report*, pp. 6 & 15
http://www.airproducts.com/~/media/Files/PDF/company/2013-sustainability-report.pdf

AT&T

Supplier Sustainability Awards

- **Water Use Category**
  Water & Energy Systems Technology, Inc. (WEST, Inc.), for their contribution enabling AT&T to save 6.6 million gallons of water since November 2011 at cooling towers in Arizona through use of the NanoFiltration system.

Source: *AT&T 2012 Sustainability Report Highlights,* p. 4
http://att.centralcast.net/csrbrochure12/Default.aspx

Avon Products

Resource Center
Avon Positions and Policies

Avon Products, Inc. and Consumer Safety: Nanotechnology

Avon Products, Inc. uses a limited number of ingredients characterized as nanomaterials, each with an average particle size of less than 100 nanometers. These are primarily titanium dioxide or zinc oxide, which are used in a wide range of cosmetic products to provide protection against the ultraviolet (UV) rays of the sun.

Nanopigments, when used in sun products, protect the skin by deflecting UV light more effectively than larger sized particles. Sunscreens can now also rub in clear without leaving white marks thanks to nanotechnology making staying safe in the sun much more appealing to people and ultimately improved protection against UV-induced damage.

The safety of titanium dioxide and zinc oxide has long been established. Both are specifically approved for use in cosmetics by the European Commission, following their stringent rules surrounding manufacture and safety assessments. In addition, in 2006, Australia's Therapeutic Goods Administration (TGA) conducted a comprehensive safety assessment of the use of titanium dioxide and zinc oxide nanoparticles in sunscreens and concluded there was no public health concern.

The safety of each of the ingredients characterized as a nanomaterial currently used by Avon has been individually and fully evaluated by our scientists before being permitted for use in cosmetic products. Avon's evaluation included a specific assessment of the potential for nanosized particles of these materials to be absorbed through the skin. We will continue to closely monitor the scientific literature on nanoparticles and, if we determine that a particular ingredient can no longer be considered to be used safely, we will discontinue its use.

Europe approved an updated cosmetic regulation [referred to as the recast to EU Cosmetic Directive] that will introduce new reporting requirements for all cosmetic products containing nanomaterials. This new regulation will be effective starting in 2013 and Avon will of course fully comply with the new EU requirements.

Consumers can be assured that any cosmetic or personal care product that carries the Avon name has undergone thorough safety evaluation and can be used with the utmost confidence.

Product ingredient information can be found at http://cosmeticsinfo.org/.

For inquiries about the safety of Avon products, please contactavoncr@avon.com.

Source: *2012 Corporate Responsibility Report*
http://www.avoncompany.com/corporatecitizenship/corporateresponsibility/resourcecenter/policies_and_procedures/nanotechnology.html

Celgene

Our Global Company
Operational Structure

Celgene Oncology has come about from an expanded view of indications in which we believe we can make a significant contribution. In particular, solid tumor cancers are a natural extension of the success we have achieved in hematology. Our innovative compounds are showing promise in a range of tumor types. Our principal therapy combines a traditional taxane with human albumin through a unique nanotechnology-based formulation process. The resulting product delivers more of the drug to its intended destination, while simultaneously minimizing solvent related safety concerns.

Source: *Our Path Towards a Healthy Future: Celgene 2013 Responsibility Report,* p. 17
https://www.celgene.com/content/uploads/2014/01/CLGN_RR2013_01-02-20141.pdf

Colgate-Palmolive

Performance
Commitment to Safety and Quality

- Colgate does not use nanotechnology in its products. Any new potential nanoparticle ingredient will undergo a safety assessment prior to use in any Colgate product.

Source: *Colgate Sustainability Report 2012: Giving the World Reasons to Smile*, p. 27
http://www.colgate.com/Colgate/US/Corp_v2/LivingOurValues/Sustainability_v2/Colgate_Sustainability2012.zip

Cummins

Environment
Products

Cummins Filtration

Cummins Filtration provides high quality, high performance integrated filtration system solutions to protect equipment, offering customers the best possible solutions while remaining mindful of its responsibilities to the environment. The business recently introduced its advanced nanotechnology based media, NanoNet™, designed for engines operating under the stringent requirements of the very latest EPA and European emissions standards.

A first for fuel filtration, NanoNet traps 98.7 percent of all hard particles at 4 microns – 12 times smaller than the smallest particle visible to the human eye. This proprietary media provides unmatched protection for today's high pressure common rail fuel systems essential to clean emissions.

Source: *Sustainability Report 2012-2013*, p. 34
http://cmipef.cummins.com/CMIPEFMIG/CumminsNA/SiteContent/en/BinaryAsset/Attachments/Sustainability/SR-2013-Full%20Report-0514-Web.pdf

Dow Chemical

The Economic Impact of Sustainability

EC4 Significant financial assistance received from government
Funding Program: European Commission
Program Title: New NANO-technology based high performance insulation FOAM system for energy efficiency in buildings.
Project Face Value ($MM)*: 4.8
*The dollar figure listed is for the entire value of the program that is receiving support.
The value of the direct government support does not equal the face value in most cases.
Many programs have multiple participants along with Dow.
Programs were active in 2012; however, many are multi-year.

Source: *2012 Annual Sustainability Report*, p. 48
http://www.dow.com/sustainability/pdf/35865-2012%20Sustainability%20Report.pdf

E. I. du Pont de Nemours

Letter from Linda J. Fisher
Vice President of DuPont Safety, Health & Environment and Chief Sustainability Officer

In the new category of Food Security, DuPont has set goals to help ensure sustainable food production in order to ultimately end world hunger and guarantee food safety. We're investing more than $3 million each day on research and development to this end, and we've already begun to see progress in our goals to strengthen agricultural systems and make food more available and nutritious.

We've made such substantial progress toward our 2015 commitments that the time has come for us to look more broadly toward the future. We're focused now on determining our 2020 sustainability goals, as well as defining the ways in which we can make new leaps and bounds toward our vision of solving the world's greatest challenges. Our perspective is that new technologies - such as biotechnology and nanotechnology – offer compelling benefits, and should be part of the suite of solutions that help bring safe and nutritious food to the world, decrease our dependence on fossil fuels, and safeguard people and the planet. Therefore societal acceptance of these technologies will be critical. We're committed to working closely with stakeholders to understand concerns, to make sure our solutions are safe, and to be transparent about our work in these areas. We know that our ability for future growth is contingent upon our continued effort to be a socially and environmentally responsible corporate citizen.

Source: *Welcome to the Global Collaboratory™: DuPont 2013 Sustainability Progress Report,* p. 4
http://www.dupont.com/content/dam/assets/corporate-functions/our-approach/sustainability/documents/2013DuPont%20Sustainability%20Report_web.pdf

EMC

EMC Sustainability Materiality Assessment

Note: In a graphic ranking 26 issues along two axes: "Impact to External Stakeholder" and "Impact to EMC," "nanomaterials" was included in the "Monitor" quadrant. The other three quadrants were "Engage and Assess," "Invest, Engage When Appropriate" and "Invest and Engage."

Source: *Thinking Forward: 2012 EMC Sustainability Report*, p. 135
http://www.emc.com/collateral/brochure/2012-emc-sustainability-report-br.pdf

Estee Lauder

Corporate Responsibility
Latest Updates
Viewpoints

Nanotechnology
Our statement

In our continuing efforts to keep our consumers informed, we are sharing the following updated information regarding nanotechnology.

Our 2010 Corporate Responsibility report states that we do not formulate using nano particles, which we were defining at the time as ingredients intentionally processed to be nano sized. However, we have since identified a small number of products that do contain a limited number of these nano sized ingredients. The definition of "nano" terms as they relate to cosmetics ingredients continues to evolve in accordance with emerging scientific study. In the future, reference to "nano" may capture more than ingredients which are intentionally manufactured to be nano sized. We will continue to pay close attention to the dialogue on nano. We will evaluate our use of these ingredients consistent with prevailing scientific opinion, related regulations, and our commitment to bringing our consumers innovative products of the highest quality.

Source: "Corporate Responsibility" section of website
http://www.elcompanies.com/Pages/Nanotechnology.aspx.

Ford Motor

Our Blueprint for Sustainability
Materiality Analysis
Materiality Matrix
High Impact, Medium Concern

> **Climate Change**
> **Cleaner Vehicle Technologies**
>
> Ford's development of low-carbon technologies, including hybrids, electric vehicles, clean diesel, fuel cells; also emerging technologies such as nanotechnology….

Climate Change and the Environment
Greening Our Products

Sustainable Technologies and Alternative Fuels Plan
Weight Reductions
Technology Overview

Unibody vehicle designs reduce weight by eliminating the need for the body-on-frame design used in truck-based products. We are also using lightweight materials, such as advanced high-strength steels, aluminum, magnesium, natural fibers, and nano-based materials to reduce vehicle weight. And, some of our advanced engine and transmission technologies, such as EcoBoost and our dual-clutch PowerShift transmissions, further reduce overall vehicle weight.

Deployment

Ford researchers are also investigating additional new lightweight materials. For example, we are investigating and developing:

- Nanotechnology to model material properties and performance at the nano-scale, which will allow us to develop better materials more quickly and with lower research and development costs.
- Nano-filler materials in metal and plastic composites, to reduce their weight while increasing their strength. For example, we are developing the ability to use nano-clays that can replace glass fibers as structural agents in reinforced plastics. Early testing shows plastic reinforced with 5 percent nano-filler instead of the typical 30 percent glass filler has strength and lightweight properties that are better than glass-reinforced plastics.

Ford is also working to understand the health and safety issues that may be posed by nano-materials. Ford has joined with other automakers under the U.S. Council for Automotive Research umbrella to sponsor research into nano-materials' potential impact on human health and the environment. This research has addressed many health- and environment-related questions so that we can focus our nano-materials research and development in areas that will be most beneficial.

Sustainable Materials
Improving Vehicle Interior Environmental Quality and Choosing Allergy-Tested Materials

As part of our efforts to deliver healthy vehicle interiors, we are also researching microbial populations on vehicle interior surfaces with the goal of creating a cleaner, more aesthetically pleasing environment for our customers. Microscopic organisms, including mold and mildew, can spread over a variety of surfaces, leading to discoloration and even unpleasant odors. We worked with a team from the University of Michigan to evaluate the concentration and growth of microbes in vehicles. After identifying the hot-spot locations for microbial growth, we are now developing and testing part-coating formulations that could resist and potentially even reverse microbial growth, including silver-ion, ammonium salt and polyolefin wax with a nano-silver coating. Parts with the antimicrobial-treated coating are now undergoing real-world testing in a number of Ford development vehicles, and the coating is being evaluated for potential use in future Ford vehicle programs.

Source: *Sustainability 2012/13*, pp. 48, 203-204 & 256
http://corporate.ford.com/doc/sr12.pdf

Goodyear Tire & Rubber

Industry stewardship
World Business Council for Sustainable Development (WBCSD)

Goodyear is a leader in the Tire Industry Project (TIP) of the WBCSD, an industry group including 11 of the world's largest tire manufacturers. As a CEO-led global association of more than 200 international companies focusing on business and sustainable development, the WBCSD is regarded as a catalyst in global policy development, representing and promoting the role of business in achieving sustainable development.

TIP's current work is focused on:

- Materials, which include life cycle analysis (LCA) to understand specific chemical impacts; and
- Nanomaterials, which include cooperative work with the OECD (Organisation for Economic Co-operation and Development) to examine sustainable development and use of nanomaterials by the tire industry.

Source: 2012 "Corporate Responsibility" Website, Text Version, p. 20
http://www.goodyear.com/responsibility/pdf/crr12_updated.pdf

Hewlett Packard

Environment
Materials
Using Less Material

Nanotechnology

Nanotechnology holds long-term promise for creating electronics applications that require fewer materials and consume less energy. Since 1995, HP Labs has led research in the areas of nanoarchitecture, nanoelectronics, nanomechanics, and nanophotonics. Outcomes of this research include advances in memristor-based computer memory, which has the potential to run 10 times faster and use 10 times less power than an equivalent flash memory chip.

We recognize that properties of matter can depend on size and shape at the nanoscale level. We consider potential health and safety issues of nanostructured materials as an integral part of our research program that seeks to find applications for such materials in our business. In 2012, HP developed a nanomaterial risk assessment tool to help assess and manage health and safety risks associated with the use of these materials. The tool helps determine the best way to handle hazards using previous findings and applications and accounting for potential incomplete information on health hazards and exposure scenarios.

Source: *HP 2012 Global Citizenship Report,* p. 41
http://h20195.www2.hp.com/V2/GetPDF.aspx/c03742928.pdf

Intel

Company Profile
Business Organization and Operations

Following the manufacturing process, the majority of our components are subject to assembly and test. We perform our components assembly and test at facilities in Malaysia, China, Costa Rica, and Vietnam. To augment capacity, we use subcontractors to perform assembly of certain products, primarily chipsets and networking and communications products. In addition, we use subcontractors to perform assembly and test of our mobile phone components. Our NAND flash memory products are manufactured by IM Flash Technologies, LLC and Micron Technology, Inc. using 20-nanometer (nm), 25nm or 34nm process technology, and assembly and test of these products is performed by Micron and other external subcontractors.

Financial Results and Economic Impact
2012 Financial Results

Worldwide economic growth in 2012 was significantly lower than we had anticipated entering the year, and the PC market segment was impacted by the growth of tablets, as these devices compete with PCs for consumer sales. Although our financial results were below our initial expectations, we launched cutting-edge products in every major business segment and extended our manufacturing leadership. We ramped shipments of 22nm processors with Intel's breakthrough 3-D Tri-Gate transistor technology while building our next-generation 14nm factory network and developing 10nm and smaller technologies. We estimate that we have about a 2-year process technology lead and about a 3.5-year lead in introducing revolutionary transistor technologies such as strained silicon, High-K Metal Gate, and Tri-Gate into high-volume manufacturing, compared to our nearest competitor.

Product Energy Efficiency and Product Ecology
Improving Product Energy Efficiency

In 2012, we ramped shipments of 22 nanometer (nm) processors with Intel's breakthrough 3-D Tri-gate transistor technology. The new transistors allow chips to operate at lower voltage with lower leakage providing significantly improved performance and energy efficiency compared to previous generations of transistors. The capabilities give designers the flexibility to choose transistors targeted for low energy or high performance, depending on the application. The 22nm 3-D transistor technology enables up to a 37% increase in performance at low voltage compare to Intel's 32nm planar transistors. Alternatively, the new transistors consume less than half the power of 2-D transistors on 32nm chips operating with similar performance. We estimate that we have about a 2-year process technology lead and about a 3.5-year lead in introducing revolutionary transistor technologies such as strained silicon, High-K Metal Gate and Tri-Gate into high volume manufacturing, compared to our nearest competitor.

Enabling the Ecosystem
Higher Education

To accelerate the adoption of cutting-edge technology in engineering education and prepare students for careers in critical technology areas, Intel works with universities to develop and disseminate curricula on advanced topics, such as nanotechnology, parallel programming, and embedded systems. For more information, visit the Complementing University Curricula Efforts web site.

Our Global Supply Chain
Top 75 Production Materials, Capital, and Logistics Suppliers

Nanometrics Inc.

Source: *Intel Inside: 2012 Corporate Responsibility Report,* pp. 8, 25, 69, 82 & 93
http://csrreportbuilder.intel.com/PDFFiles/CSR_2012_Full-Report.pdf

International Business Machines

The IBMer
Employee Well-Being

Leading the way in professional communities

Participation in professional communities contributes to the body of research, best practices and standards development that helps communities at large. IBM sponsors and collaborates with several US university-based consortia research programs to help ensure the safe use of current, new and emerging materials critical to the semiconductor industry. Included are:

- Albany College of Nanoscale Science & Engineering EHS research on workplace safety and toxicity of nanomaterials

IBM is actively involved in the US National Science Foundation sponsored Center for Environmental Implications of Nanotechnology (CEINT), a consortium of universities and researchers. The results of this research will be foundational as the industry moves into a post-CMOS world.

Environment
Process Stewardship

Nanotechnology

By definition, nanotechnology is the application of scientific and engineering principles to make and utilize very small things (dimensions of roughly 1 to 100 nanometers), creating materials with unique properties and enabling novel and useful applications. It involves an ever-advancing set of tools, techniques and unique applications involving the structure and composition of materials on a nanoscale.

Nanotechnology is already part of a wide variety of products—from cosmetics and sunscreens to paints, clothing and golf equipment. It can make products lighter, stronger, cleaner, less expensive and more precise, and has been critical to advancements in the IT industry.

IBM Research became involved in the world of nanoscience in 1981 when Gerd Binnig and Heinrich Rohrer invented the scanning tunneling microscope, revolutionizing our ability to manipulate solid surfaces the size of atoms. Since that time, IBM has achieved a number of developments in the field—from moving and controlling individual atoms for the first time and developing logic circuits using carbon nanotubes to incorporating subnanometer material layers into commercially mass-produced hard disk drive recording heads and magnetic disk coatings.

We were also one of the first companies to create safe work practices and health and safety training for our employees working with nanoparticles. IBM, along with the International SEMATECH Manufacturing Initiative (ISMI) and other semiconductor companies, is participating in a collaborative study with the National Institute for Occupational Safety and Health (NIOSH) and the College of Nanoscale Science and Engineering (CNSE) of the University at Albany-SUNY to monitor potential workplace exposure to nanoparticles during chemical mechanical planarization (CMP) operation and maintenance.

IBM's current nanotechnology research aims to devise new atom- and molecular-scale structures and methods for enhancing information technologies, as well as discovering and understanding their scientific foundations. We believe these technologies can bring with them significant social and environmental benefits.

The following are highlights of some of our latest nanotechnology research milestones:

- IBM announced a major advance in the ability to use light instead of electrical signals to transmit information for future computing. The breakthrough technology—called silicon nanophotonics—allows the integration of different optical components side-by-side with electrical circuits on a single silicon chip using, for the first time, sub-100 nanometer semiconductor technology. Silicon nanophotonics takes advantage of pulses of light for communication and provides a superhighway for large volumes of data to move at rapid speeds between computer chips in servers, large data centers and supercomputers, thus alleviating the limitations of congested data traffic and high-cost traditional interconnects.
- Researchers from IBM and the Institute of Bioengineering and Nanotechnology announced their development of an antimicrobial hydrogel that can break through diseased biofilms and completely eradicate drug-resistant bacteria upon contact. The synthetic hydrogel, which forms spontaneously when heated to body temperature, is the first-ever to be biodegradable, biocompatible and non-toxic. Comprised of more than 90 percent water, if commercialized, it is ideal for applications like creams or injectable therapeutics for wound healing, implant and catheter coatings and skin infections and to help combat serious health hazards facing hospital workers, visitors and patients.
- IBM scientists demonstrated a new approach to carbon nanotechnology that opens up the path for commercial fabrication of dramatically smaller, faster and more powerful computer chips. For the first time, more than 10,000 working transistors made of nano-sized tubes of carbon have been precisely placed and tested in a single chip using standard semiconductor processes. These carbon devices are poised to replace and outperform silicon technology, allowing further miniaturization of computing components and leading the way for future microelectronics.

Product Stewardship

Innovations in semiconductor manufacturing

IBM Research and IBM Systems & Technology Group continue to drive innovation in semiconductor technologies to increase computing and storage capacity while reducing the energy required for a given functionality. Two recent innovations:

- IBM has developed a process to place more than 10,000 transistors made from carbon nanotubes (CNT) onto a single chip. While significantly below current silicon-based circuit densities of more than a billion circuits on a processor, the development is an important next step in commercializing CNT-based processor technologies. CNT circuits are smaller and can potentially carry higher current densities than silicon circuits and offer a potential replacement for silicon-based processors as silicon technologies reach their physical limits.

Supply Chain
Supplier Assessment and Improvement Plans

2012 Center of Excellence for Product Environmental Compliance

IBM's global Center of Excellence (CoE) for Product Environmental Compliance has end-to-end responsibility for meeting product-related government environmental requirements. The CoE's mission includes the development of strategy, processes, deployment plans, research and development of alternate materials and technologies, and education and training materials. The CoE also is an active member in industry and regulatory bodies around the world. Year over year, environmental regulations continue to increase in number and complexity. The types of regulations we address include prohibited substances, product takeback programs, product energy usage, batteries and most recently nanotechnology regulations. In 2012, IBM successfully transitioned thousands of part numbers that were affected by the conclusion of the European Union's RoHS Directive—designed to restrict the use of hazardous substances in electrical and electronic equipment—exemptions 7c3 and 11b. As of January 1, 2013, IBM products shipped into the EU are fully compliant and lead-free.

Source: *2012 Corporate Responsibility Report,* pp. 50, 67-68, 83 & 124
http://www.ibm.com/ibm/responsibility/2012/bin/downloads/ibm_crr2012.pdf

Jacobs Engineering Group

Our Processes and Tools
Operating and Maintaining
Sulfate Removal System

An Environmental Success Story for Chlor-Alkali Plants

The chlor-alkali industry produces chlorine and caustic soda in about 600 plants worldwide. A collective commitment to ensuring the best health, safety, and environmental practices in the manufacture of chlor-alkali products is essential to the sustainable development of this large and closely watched industry. Our Chemetics® Patented Sulfate Removal System (SRS) is a novel nanofiltration-based process that replaces conventional methods of sodium sulfate control in chlor-alkali plants. Based on the principle of selective filtration of molecules and ions through membranes, the SRS treats brine effluents to reduce the effluent volume and increase the sulfate concentration — both by a factor of more than 10. As an environmentally beneficial and economically attractive technology, the SRS also eliminates solid wastes and the handling of hazardous compounds associated with other treatment methods.

Source: *2013 Sustainability Report,* pp. 45-46
http://www.jacobs.com/uploadedFiles/about/Jacobs_2013_Sustainability_Report.pdf

Johnson & Johnson

Nanotechnology

Nano particles (particles under 100 nanometers in size) offer the potential to develop improved medicines, medical devices and personal care products, such as sunscreens. We continue to participate in nanotechnology scientific forums and monitor regulatory developments, such as anticipated guidelines being developed in Europe and the United States. We also research the environmental impact of nano-sized particles, investigate product safety and develop advanced protective methods for working with nano-sized materials. Our positions related to nanotechnology and genetically modified organisms are addressed in Product Quality & Safety on www.jnj.com. Our Guideline for the Responsible Use of Nanotechnology sets standards for responsible behaviors across the Corporation and provides a general framework to influence the wider global community in developing nanotechnology in a responsible manner.

Source: *2012 Corporate Responsibility & Sustainability Report,* pp. 23
http://www.jnj.com/sites/default/files/pdf/2012-JNJ-Citizenship-Sustainability-ANNUAL-REPORT-June2013-FINAL062413.pdf

Lockheed Martin

We're applying nanotechnology to create materials that are 50 times stronger and 10 times lighter than steel.

Engineering and Innovation
Our Performance

Nanotechnology

Nanotechnology can offer significant sustainability benefits by reducing materials use. Already, we are deploying carbon nano-materials to build stronger, lighter and higher-performing structures with additional electrical and mechanical properties for use on the F-35 aircraft and the Juno spacecraft.

In 2012, we launched or joined a series of high-profile initiatives to further develop this transformational technology.

- We established an industry-led consortium that will work to accelerate the development of affordable, high performance carbon nanostructure enhanced materials and transition them into products and commercial markets. The Carbon Nanostructures Consortium is part of the Materials Genome Initiative (MGI), announced by the White House in an effort to double the speed and cut the cost of discovering and deploying new advanced materials and to revive and revolutionize American manufacturing.
- We joined several companies to sponsor nanotechnology research at the University of Texas-Austin that could lead to advances in multi-scale nanomanufacturing, modeling and simulation.
- We announced a new collaboration with the London (UK) Centre for Nanotechnology, a world-class research hub, to develop transformational quantum and nanotechnologies.

Where We Are Going

Nano-Bio Manufacturing Consortium

We actively pursue innovative fields of science and engineering that offer potentially significant sustainability benefits. For example, in early 2013, the U.S. Air Force Research Laboratory announced that the FlexTech Alliance of San Jose, Ca., which leads a team including Lockheed Martin's Advanced Technology Laboratories, will receive a $5.4 million award. The team will form a consortium to build prototypes to remotely monitor the health and performance of their systems in real time. The Alliance will launch a new manufacturing initiative with world-class researchers that will operate at the junction of nanotechnology, biotechnology, additive manufacturing and flexible electronics.

Source: *The Science of Citizenship: Sustainability 2012*, pp. 15 & 21-23
http://www.lockheedmartin.com/content/dam/lockheed/data/corporate/documents/2012-LM-sustainability-report.pdf

Merck

NANOTECHNOLOGY

Merck supports the use of nanotechnology to develop innovative drugs, vaccines and consumer products that address the unmet medical and wellness needs of people and animals.

Nanotechnology broadly describes the use of very small materials—ranging from the extreme size reductions of normal materials to unique, minute substances such as carbon nanotubes and other exotic materials.

The testing required for all drugs ensures that nano-based pharmaceuticals are safe and effective for patient use. Our safety and health professionals closely monitor the developments in this area; based on current knowledge of nanoparticles, our existing methods for assessing risks to workers and the environment are valid, and our existing controls are well suited to minimize exposure to employees and the environment.

Examples of how Merck is using nanotechnology:

- Human Health: EMEND® (aprepitant), uses a nanoscale milling approach to make its granules very small, so that they are more easily absorbed by the digestive tract
- Merck Animal Health (Intervet): Nanoscale milling is used for the active ingredient in PANACUR® (fenbendazole) to produce a stable and more easily re-suspendable formulation
- Merck Consumer Health: Some Coppertone products contain micronized zinc oxide, which provides improved broad-spectrum UVA/UVB protection from the sun's damaging rays, reducing the risk of sunburn, early skin aging and skin cancer. Nanoparticles of titanium dioxide (TiO2) and zinc oxide (ZnO) have been extensively studied, and current scientific data, including our own studies, demonstrate that skin contact with these particles does not represent a health concern.

Source: *Corporate Responsibility Report 2012*, pp. 164-65
http://reportbuilder.addison.com/input_pdf_files/2013-Merck-Responsibility/MRK_CR12_full_report.pdf

Mondelez International

Well-being
Safety of our People and Products
Ensuring Safe Food
Nanotechnology

Nanotechnology is an emerging scientific field. It involves the design and application of structures, devices and systems by controlling their shape and size at an extremely small scale - in range of one-to-100 nanometers (for reference, one nanometer is one-billionth of a meter). And this technology holds a lot of promise across industries.

Currently we're not using nanotechnology. But as a leading food company, we need to understand the potential this technology may hold for us in terms of food safety, product quality, nutrition and sustainability. That is why our research and development teams always keep their eyes on the scientific research, as well as consider potential applications where nanotechnology may be used in packaging material.

In particular, we're looking at packaging that requires less material, which helps to reduce waste. We would only consider those uses that meet regulatory requirements and are considered safe by the scientific community. We also take into account what our consumers think and feel.

Our highest priority is the safety of our products and our consumers. We thoroughly look at the ingredients and materials we use - no matter the size. We also talk with outside experts on specific questions related to ingredient and product safety. If we ever intend to use nanotechnology, we will make sure that the appropriate environmental, health and safety concerns have been addressed. This includes going through our own stringent quality-control processes, as well as working with our suppliers to make sure the proper assessments have been completed.

If you want to learn more, take a look at the National Nanotechnology Initiative and Woodrow Wilson Project for Emerging Nanotechnologies.

Source: "Well-being" section of website
http://www.mondelezinternational.com/well-being/safety-of-our-people-and-products/ensuring-safe-food

Texas Instruments

Sustainable manufacturing
Looking ahead: 2013 and beyond

- Work with the International Sematech Manufacturing Initiative and the Engineering Research Center for Environmentally Benign Semiconductor Manufacturing to better understand and mitigate the risks associated with using nanomaterials.

Source: *2012 Corporate Citizenship Report Summary*, p. 10
Report Summaryhttp://www.ti.com/corp/docs/csr/2012/downloads/CCR_Report2012_Summary_V3.pdf

Thermo Fisher Scientific

Dedicated to Discovery: Our Business
Products that Support Health and the Environment

Environmentally Friendly Products for Advanced Research

NanoDrop instruments require smaller samples and fewer solvents, and offers researchers a simple pipette, measure and wipe-clean process that saves time in the lab.

Source: *Our Mission in Action: 2012 Corporate Social Responsibility Report*, p. 7
http://www.thermofisher.com/global/en/pdf/CSR_report_2012.pdf

Appendix C

S&P 500 Companies in the Nanotechnology Consumer Products Inventory

Company	Product	Nanomaterial or Function	Source
Apple	iMac® with Intel® Core 2 Duo	45 nm processors	Unsupported claim by manufacturer [1]
	iPhone®	Miniaturization	From 2007; Availability/nano claim can no longer be verified[2]
	iPod Nano®	Memory chips	Source not manufacturer[3]
	Mac Pro®	Silicon	Not available
Coca Cola[+]	Lemon Lime Powerade	Titanium dioxide as anticaking agent	Source not manufacturer[3]
	White Cherry Powerade	Titanium dioxide as anticaking agent	Source not manufacturer[3]
Colgate-Palmolive*	Colgate Toothpaste[+]	Titanium dioxide as cosmetic	Source not manufacturer[3]
	Ultrabrite Toothpaste	Titanium dioxide as cosmetic	Source not manufacturer[3]
E. I. du Pont de Nemours	Light Stabilizer 210 (sun protection for plastics)	Titanium dioxide	Not available
	Olight® Organic Light Emitting Diode (OLED)	Miniaturization. Nanofilm - 100 nm thickness	Source not manufacturer[3]
Gap	Nano-Care® Stressfree Khaki	Carbon nanotube	From 2007; Availability/nano claim can no longer be verified2
General Mills[+]	Trix Cereal	Titanium dioxide as anticaking agent	Source not manufacturer[3]
General Motors	Automotive Exterior	Nanoclay for hardness and strength	Unsupported claim by manufacturer[1]
Hershey's[+]	Breathsavers Mints, Cadbury Milk Chocolate Bar, Hershey's Bliss Dark Chocolate, Hershey's Bliss White Chocolate, Hershey's Chocolate Syrup, Hershey's Cookies n Cream Bar, Hershey's Milk Chocolate Bar, Hershey's Special Dark Bar, Mini Whopper Eggs	Titanium dioxide as anticaking agent and/or pigment	Source not manufacturer[3]
Honeywell	Hite Brewery beers	Nano-nylon material in plastic beverage bottles	Not available
Intl Business Machines	IBM® PowerPC® 970FX/970MP Processors	Miniaturization - 90 nm silicon on insulator	Extensively verified claim by manufacturer [4]

Company	Product	Nanomaterial or Function	Source
Intel	Intel® Celeron® 4 Processor, Intel® Core™ Duo Processor, Intel® Pentium® D Processor, Intel® StrataFlash® Cellular Memory	Miniaturization – copper and/or silicon; nanoparticles, 90 nm and/or 65 nm	Manufacturer supported claim[5]
	Intel® Pentium® 4 Processor	Miniaturization – silicon	Unsupported claim by manufacturer[1]
J.C. Penney	350TC Nano-Tex® Sheet Set by Studio	Nanotechnology used in sheet	Not available
J.M. Smucker[+]	Smuckers Orange Cream Shell	Titanium dioxide as anticaking agent	Source not manufacturer[3]
Kellogg[+]	Mothers Oatmeal Iced Cookies	Titanium dioxide as anticaking agent	Source not manufacturer[3]
	Vanilla Milkshake Pop Tarts	Titanium dioxide as anticaking agent	Source not manufacturer[3]
Kraft Foods[+]	Jello Banana Cream Pudding, Kraft American Single, Kraft Jet Puffed FunMallows, Kraft Jet Puffed MarshMallows, Kraft Mayo, Kraft Miracle Whip, Kraft Parmesan Cheese, Kraft Velveeta, Philadelphia Cream Cheese	Titanium dioxide as anticaking agent	Source not manufacturer[3]
Motorola Solutions	Motorola® Organic Light Emitting Diodes	Miniaturization - Nanofilm	Unsupported claim by manufacturer[1]
Stanley Black & Decker	DeWalt Cordless Power-tool Set	Catalyst for batteries	Manufacturer supported claim[5]
Whirlpool	Whirlpool AKT 725/IXL Gas Hob	Titanium dioxide for environmental treatment	Not available

[*]Colgate-Palmolive reported in its *2012 Sustainability Report* that it does not use nanotechnology in its products.
[+]Companies and their products have been removed from the inventory pending a review of the source.
[1]The manufacturer claims that the product contains nanotechnology, but no specific information is provided to support this claim.
[2]Archived product in database.
[3]Nanotechnology claim is provided by source other than manufacturer, typically a news story, research paper or third-party stores selling the product.
[4]The manufacturer has provided information supporting the nanotechnology claim and this claim was verified by an independent source. Actual product has been tested for nanomaterial or supporting documentation references such product or product was described in more than one published scientific documents (such as research studies, patents or reports).
[5]The manufacturer has provided information supporting the nanotechnology claim. For example, the manufacturer provides a datasheet with nanomaterial characteristics, electron microscopy images, etc.

Source: Project on Emerging Nanotechnologies (2013). Consumer Products Inventory. Retrieved in October 2013 from http://www.nanotechproject.org/cpi.
The Consumer Products Inventory has been compiled by the Project on Emerging Nanotechnologies in the Science and Technology Innovation Program (STIP) at the Woodrow Wilson International Center for Scholars, in collaboration with the Virginia Tech Center for Sustainable Nanotechnology. The inventory contains 1,628 consumer products that have been introduced to the market between 2005 and October 2013.

Resources

People

The following people generously agreed to share their knowledge and time in interviews for this report:

Dr. William K. Boyes
Interim Associate National Program Director
Chemical Safety and Sustainability
Office of Research and Development
U.S. Environmental Protection Agency

Shaun F. Clancy, Ph.D.
Director and Regional Head
Product Regulatory Services
Evonik Corp.

Danielle Fugere
President
As You Sow

Charles L. Geraci, Jr., Ph.D., CIH
Coordinator
Nanotechnology Research Center
National Institute for Occupational Safety and Health

Ian Illuminato
Health and Environment Campaigner
Friends of the Earth

Todd Kuiken
Senior Program Associate
Science and Technology Innovation Program
Woodrow Wilson International Center for Scholars

Jeffery T. Morris, PhD
Deputy Director (Programs)
Office of Pollution Prevention & Toxics
U.S. Environmental Protection Agency

David Rejeski
Director
Science & Technology Innovation Program
Woodrow Wilson International Center for Scholars

Jennifer Sass, Ph.D.
Senior Scientist
Natural Resources Defense Council (NRDC)
Professorial Lecturer
George Washington University (SEIU Local 500)

Austin Wilson
Environmental Health Program Associate
As You Sow

Jan Youtie
Enterprise Innovation Institute
School of Public Policy
Georgia Institute of Technology

Additional resources for further exploration are listed on the following pages.

Websites

European Commission
Research in Nanosciences & Technologies
http://ec.europa.eu/research/industrial_technologies/nanoscience-and-technologies_en.html

National Nanotechnology Initiative
www.nano.gov

Project on Emerging Nanotechnologies of the Woodrow Wilson International Center for Scholars
http://www.nanotechproject.org/

Publications/Powerpoint Presentations/Videos

2014 Draft NNI Strategic Plan
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Jaideep Raje, Senior Analyst, Lux Research B.V., May 30, 2011
http://www.euronanoforum2011.eu/wp-content/uploads/2011/09/enf2011_support-commercialisation_raje_fin.pdf

Current Strategies for Engineering Controls in Nanomaterial Production and Downstream Handling Processes.
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http://www.cdc.gov/niosh/docs/2014-102/

International Challenges and Opportunities in Nanotechnology
Shaun Clancy, Evonik Industries, June 11, 2013
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Nanotechnology Research Directions for Societal Needs in 2020
Mike Roco, March 28, 2012
http://nano.gov/sites/default/files/roco.pdf

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Mihail Roco, Chad Mirkin and Mark Hersam, September 30, 2010
http://www.wtec.org/Nano_Research_Directions_to_2020.pdf

Background Paper 2: Finance and Investor Models in Nanotechnology
Tom Crawley, Pekka Koponen, Lauri Tolvas and Terhi Marttila, March 16, 2012
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Nanotechnology: A Policy Primer
John F. Sargent Jr., Congressional Research Service, June 24, 2013
http://www.fas.org/sgp/crs/misc/RL34511.pdf

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Lloyd's Emerging Risks Team, Lloyd's, 2007
http://www.lloyds.com/~/media/Lloyds/Archive/Lloyds%20Market%20Gallery/Lloyds%20Market%20Gallery/ER_Nanotechnology_Report.pdf

Nanotechnology and Environmental, Health, and Safety: Issues for Consideration
John F. Sargent, Congressional Research Service, January 20, 2011
http://assets.opencrs.com/rpts/RL34614_20110120.pdf

Nanotechnology, climate and energy: Over-heated promises and hot air?
Ian Illuminato and Georgia Miller, Friends of the Earth, November 2010
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Report to the President and Congress on the Fourth Assessment of National Nanotechnology Initiative
Executive Office of the President, President's Council of Advisors on Science and Technology, April 2012
http://www.whitehouse.gov/sites/default/files/microsites/ostp/PCAST_2012_Nanotechnology_FINAL.pdf

Slipping Through the Cracks: An Issue Brief on Nanomaterials in Food
As you Sow, February 2013
http://www.asyousow.org/health_safety/nanoissuebrief.shtml

Small Sizes that Matter: Opportunities and Risks of Nanotechnologies
Allianz AG and The Organisation for Economic Co-operation and Development, 2005
http://www.oecd.org/dataoecd/32/1/44108334.pdf

Sourcing Framework for Food and Food Packaging Products Containing Nanomaterials
As you Sow, December 2011
http://www.asyousow.org/health_safety/nanoframework.shtml

Time to Reassess the Promise of Nanotechnology?: An Analysis of Research, Developments and Commercialization
Jan Youtie and Philip Shapira, Feb. 19, 2013
http://vimeo.com/60019397

Tiny Ingredients, Big Risks: Nanomaterials Rapidly Entering Food and Farming
Ian Illuminato, Friends of the Earth, May 2014
http://libcloud.s3.amazonaws.com/93/25/c/4723/2014_Tiny_Ingredients_Big_Risks_Web.pdf

Seminars and Symposiums

2013 NNI Strategic Planning Stakeholder Workshop
U.S. National Nanotechnology Initiative, June 11 - 12, 2013
http://www.nano.gov/node/997

International Symposium on Assessing the Economic Impact of Nanotechnology
Organisation for Economic Cooperation and Development and the U.S. National Nanotechnology Initiative, March 27 - 28, 2012
http://www.nano.gov/node/729