Sustainable U.S. Manufacturing: Chemical and Allied Industries

Technology Area 3:
Materials for Sustainable Manufacturing

Technologies developed for the future of sustainable manufacturing will require advances in materials. The U.S. Chemical and Allied industries will benefit from the development of these materials through the deployment of new products, reduced energy usage and a more secure energy supply. The Chemical and Allied industries provide a willingness, scale, flexibility, and talented workforce to assist in the discovery and production of advanced materials.

A. NATIONWIDE ADVANTAGES

- Accelerated development of advanced materials will support the development of renewable, diverse (e.g., solar, wind and biomass) and secure (ubiquitous and home grown) energy resources and other energy efficient technologies
- Attainment of unique global competitive advantage by producing, at low cost, revolutionary sustainable manufacturing technology

The U.S. industrial sector accounts for about one third of all energy used in the United States consuming approximately 32 quadrillion Btu (10^{15} Btu) of energy annually and emitting about 1,680 million metric tons of carbon dioxide associated with this energy use. Developing advanced materials to support more efficient and sustainable manufacturing practices and energy generation will reduce dependence on imported oil, lower the burden of CO_2 management and improve energy supply security, sustainability and competitiveness.

B. NATIONWIDE SAVINGS, REVENUE, JOBS, & REDUCTION IN EMISSIONS

- Sustainable replacement of 320 trillion Btu/yr natural gas - equivalent to the consumption of 7.4 million households
- Sustainable replacement of **24** million barrels of oil per year - equivalent to 2.4 days of all U.S. oil imports
- Sustainable replacement of **5,300** MW of electric power - equivalent to the consumption of 3.7 million households
- Lowering greenhouse gas emissions by **65** million tons - equivalent to removing 13 million cars from U.S. roadways
- Increasing revenue to support up to **55,000** direct jobs
- Providing **$1.6** billion per year in new corporate tax revenue

The ability to improve manufacturing technologies is limited by the physical properties of materials of construction. Improvements in properties such as operating temperature tolerance, resistance to corrosion and chemical attack, suitability for specific chemical reactions and cost will be needed to increase the efficiency and flexibility of manufacturing processes and technologies. In particular, research, development and demonstration (RD&D) is needed in structural and support materials, materials for monitoring and analysis, and in innovative, low cost manufacturing methods to produce these materials.

C. NATIONWIDE FISCAL REQUIREMENTS

- Federal investment of $150 million to initiate, augment and promote targeted RD&D partnerships
- Federal incentives and investments to expand RD&D-related postgraduate education and develop a highly skilled workforce

Collaborative work between the Chemical and Allied industries, materials suppliers and manufacturers, and government will permit advances in the following six (6) RD&D areas:

1.) Alternative Energy Materials –The Chemical and Allied industries currently supply many essential materials for solar, wind and other alternative energy technologies. Solar and wind energy sources are inherently intermittent, which limits the ability of these resources to replace fossil fuels without creating grid instability. Enabling these renewable energy sources will require advances in batteries (including flow batteries) for energy storage, improved switching and transmission linkages, and better solar-thermal connections. Improvements in insulation, protective coatings, lubricants and structural materials (like carbon fiber, epoxies and other resins, and light-weight, high-strength materials) will improve energy efficiency and durability. RD&D can also lead to more efficient production of polysilicon and other primary materials, and the development of other innovative photo-reactive thin films, coatings and dyes. Thermal salts show promise for efficient heat transfer and thermal-energy storage, but still require efficiency improvements or the development of replacement technologies.

Process design improvements will lead to economies of scale for production of these materials, decrease production and installation costs, and increase the viability of alternative energy sources based on materials derived from these processes.

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2.) Biomass to Energy — For biomass to energy applications, research continues to improve the separation, purification and processing technologies required for more efficient utilization of renewable feedstocks. Improved materials are needed to redesign chemical processes and enable burner and boiler design for easier biomass use, maintenance, fuel flexibility and cleaning. Material properties that will benefit from continued development include higher temperature stability, and greater resistance to chemical attack or biological fouling. In addition, the development of alternative chemical products – made from combustion byproducts or produced in other ways from sustainable feedstocks – will require new materials for safe handling, storage, and use.

3.) Enabling Technologies (Purity, Reliability, Detection) — The Chemical and Allied industries need to pursue a number of support technologies vital to developing sustainable manufacturing. These include technologies to monitor chemical products, to detect impurities and to ensure overall product consistency and reliability. With these new technologies, the Chemical and Allied industries can design and adjust production and materials-handling processes to take advantage of different feedstocks (see **Alternative Feedstocks**), to reduce waste and to improve product performance. Level of purity is a critical factor in improving the performance of semiconductors, LEDs and other complex technologies. Similarly, fine control of product quality will enable high performance next generation battery technologies, and alloys and composites for solar and wind power applications.

4.) Efficient Hydrogen Production and Storage — As both suppliers and the largest users of hydrogen, the Chemical and Allied industries have a vested interest in this essential feedstock and potentially valuable fuel. Many new routes for the production of hydrogen, including biomass to hydrogen, waste to hydrogen, and solar hydrogen, merit RD&D investment. Methods exist for improving the energy efficiency of current production processes, including thermodynamic modeling, gasification reactor/separator design, biological production, and electrolysis. The latter can benefit from developments in electrode materials, spacer designs, solution chemistry and catalyst development. In addition, the infrastructure that supports hydrogen production and distribution will require improved materials for safe handling, storage and transport, which will enable new designs for tanks, generators and fuel cells. The expected benefits include more efficient production and decreased costs. Ultimately, this will drive increased use of hydrogen as a fuel, and the environmental benefits that this change can provide.

5.) Novel and More Effective Catalysts — Catalysts can make a previously impractical process economically feasible. Advances in catalysis can reduce the number, type, cost and amount of raw materials required to make a product while reducing byproducts and waste. RD&D into new nanostructured catalysts and biocatalysts (discovery and genetic engineering) will transform the way products are manufactured.

6.) Nanomanufacturing — Through the recognition of the value of the unique material properties achievable from nanotechnology, the United States. has led global investment in this science. Applications in the chemicals, refining, maritime and automotive sectors alone have the potential to save up to 1.1 quadrillion Btu per year, avoiding emissions of more than 60 million metric tons of carbon dioxide. Investment in RD&D can develop low-cost manufacturing processes to accelerate commercial use of innovative nanomaterials in industrial applications and energy-saving products, and enable expanded use of nanomaterials.

This technology brief describes one of six areas in need of technological advances to support sustainable growth in the Chemical and Allied industries. These six areas require significant federal investment ($1.5 billion) in RD&D, and an increase in the number (>1,000) of chemistry and chemical engineering post-graduate degree workers. The potential commercial benefits include a 65% reduction in fossil fuel use, a 34% renewable resources mix in energy and feedstock supplies, and an industry-wide reduction in GHG emissions of 63%.

The ACS Presidential Roundtable on Sustainable Manufacturing brings together industrial, government, academic, and scientific and engineering organizations to enable sustainable manufacturing in the chemical and allied products industries. The Roundtable will provide a consistent source of credible, sound information on the application of principles of sustainability to chemical manufacturing industry stakeholders to influence public policy, standard setting organizations, and third parties directly relevant to the chemical enterprise. These briefs originated from the 2009 Vision 2020 Workshop. For more information on these six areas, and how focused investment can maintain the United States' position as the leader in global RD&D, visit: www.acs.org/smrt