Sustainable U.S. Manufacturing: Chemicals and Allied Industries

Technology Area 6:

Water Conservation, Recycling and Reuse

Water, our nation's most important natural resource, also holds a fundamental role in industrial operations. The U.S. Chemical and Allied industries withdraw more than 10 billion gallons per day for process use, heating and cooling, and then discharge it back into the environment. Sustainable manufacturing goals seek near-zero discharge (i.e., closed-loop systems) that offer the potential to greatly minimize water withdrawals, save energy and reduce environmental impacts.

A. NATIONWIDE ADVANTAGES

- Conserve 4 billion gallons per day of our nation's most important resource (equivalent to the consumption of 17 million households)
- Sustainable and challenging scientific and engineering research to attract and engage our best minds

The Chemical and Allied industries rank among the most water-intensive manufacturing operations, using large quantities of process water to transport, suspend and/or solubilize materials, for heating (e.g., steam boilers) and cooling to control process temperatures, and evaporate, condense or solidify intermediate and final products. Water management has historically focused on quantity, quality and cost of sourcing and discharging water. Technology and economics both limit the recycling and reusing process for heating and cooling waters. These water streams constitute a potential energy source (i.e., their temperatures are above ambient), but have been ignored since in most cases the "low quality" energy makes current energy recovery technologies uneconomical. Energy recovery represents a significant opportunity for greater sustainability and is addressed in the **WASTE REDUCTION AND RECOVERY** brief. New research, development and demonstration (RD&D) directed at water conservation offers the opportunity to achieve nearly 100% recycle rates (i.e., near-zero discharge), recovery of useful energy, and lower water use costs.

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

- Saving **34** trillion Btu/yr in natural gas - equivalent to the consumption of 780,000 households
- Lowering greenhouse gas emissions by **6.9** million tons - equivalent to removing 1.3 million cars from U.S. roadways
- Providing revenue to potentially support **9,100** direct jobs
- Providing over $**270** million in corporate tax revenue

Considerable technical and scientific challenges remain for improving process, heating and cooling water conservation and energy recovery. Achieving a goal of near-zero discharge and improving energy recovery will require RD&D partnerships between the Chemical and Allied industries, the water supply and treatment industry, academia and the federal government. These partnerships will ensure the inclusion of all parties' and will greatly augment and hasten the Chemical and Allied industries' RD&D efforts.

C. NATIONWIDE FISCAL REQUIREMENTS

- Federal investment of $100 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

The Chemical and Allied industries' mills and plants share significant commonalities in the handling of process, heating and cooling waters. Water pretreatment typically filters solid particulates and removes dissolved ionic and organic constituents that influence process performance and product quality or that contributes to equipment corrosion and fouling. Boiler and cooling waters commonly include water treatment chemicals (e.g., biocides and corrosion inhibitors). Water post-treatment removes process constituents and treatment chemicals and adjusts water quality to meet direct discharge limits or to lower disposal costs. Closing the water loop causes the accumulation of treatment and process chemicals. These accumulations impact process performance and product quality and can accelerate corrosion and equipment damage. Successful closed-loop operations require pre- and post-treatment systems that minimize the demands on separations equipment; new separation technologies to clean the process, heating and cooling waters; and recovery of the accumulated chemicals; as well as technologies to recover low-quality energy. The necessary RD&D advances focus both on water system energy efficiencies and on water treatment. Collaborative work is needed in the following six RD&D areas:

WATER TREATMENT AND CHEMICAL RECOVERY

1.) Water Treatment Chemicals — Over time, the requirements for water treatment have become more stringent for industrial performance and product quality reasons, as well as for environmental law and policy reasons. Water treatment chemicals, including algaecides, antifoams, biocides, coagulants, corrosion inhibitors, disinfectants, flocculants, oxidants, oxygen scavengers, pH conditioners and scale inhibitors, contribute to the cost and challenge of pre- and post-treatment and recycling. Minimizing, controlling or recovering the variety of treatment chemicals and processing by-products complicate water recycling technology development. RD&D work in new chemical additives and practical and economic recovery technologies can solve these challenges.

2.) Membranes — Microfiltration, ultrafiltration and reverse osmosis (nanofiltration) membranes separate unwanted components from source, process and waste waters. Sensitive to temperature, operating pressure and the constituents in the water, the RD&D challenge is to develop lower-pressure, higher-throughput, more-energy-efficient, fouling-resistant and non-reactive membrane systems. This RD&D will require new and modified materials capable of being integrated into efficient and cost-effective membrane modules and systems. See the **MATERIALS FOR SUSTAINABLE MANUFACTURING** brief for more information on materials development needs.

3.) Sorbents — Solid sorbents remove or recover natural, process and treatment chemicals. The designing of sorbents enables the selective removal of individual chemicals. Sorbent RD&D focuses on utilizing inexpensive raw materials with high selectivity and high surface areas and those with simple, low-energy regeneration and compatibility with other system materials.

4.) Bio-Processes — Biological processes commonly serve as modes of removal of organic and ionic components from water. Technologies employ a variety of biological materials ranging from live organisms to waste biomass. RD&D should be applied to develop biological technologies that are compatible with existing, standard treatment technologies, are applicable to treatment of both aerobic or anaerobic systems, and accepting of contaminants that interact strongly with the biological operations (e.g., salts and chlorine). Organism byproducts must also be dealt with either because of the need for further treatment/removal or because buildup of these byproducts inhibits further biological activity. RD&D can advance screening for or adapting biological organisms to perform treatment activities efficiently under the diverse (and often adverse) conditions of water or wastewater streams. Surveying and identifying existing organisms and selecting or breeding/engineering organisms that can perform, survive and thrive under various industrial water conditions needs considerable new investment.

WATER AND ENERGY EFFICIENCY

5.) Manufacturing Process Optimization — RD&D directed at changing or optimizing manufacturing processes can dramatically reduce the quantity of process, heating and cooling water required. RD&D opportunities directed at processes and practices that contribute to water use should also be designed to reduce costs and create a more sustainable industry.

6.) Closed-Loop Cooling Systems —A once-thru, open-loop design that withdraws river, lake or ocean water and returns it to the same source remains the lowest cost and simplest cooling system. Once-thru systems raise sustainability concerns because of their volume, ability to increase water temperature, and potential for contamination. Conversion to closed-loop systems using ambient air for cooling substantially eliminates water withdrawal and the risk of contamination. However, closed-loop technologies involve a greater number of components, which results in higher costs. RD&D must address high ambient temperature or relative humidity operations, which impair closed-loop system performance and promote corrosion/fouling, in turn decreasing efficiency and increasing system costs. New designs (e.g., hybrid systems), alternative cooling media or technologies, advanced operating controls (e.g., monitoring of heat transfer efficiency, corrosion and biological contamination) and advanced materials, once developed will allow efficient and economical closed-loop cooling systems to become commonplace in the Chemical and Allied industries.

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