SUSTAINABLE MANUFACTURING WORKSHOP
JANUARY 6-7, 2016

University Place Hotel & Conference Center, Portland, OR

Overall Workshop Purpose

To gather input from stakeholders on future opportunities and technical challenges facing development and scale-up of transformative technologies, processes, and equipment for sustainable manufacturing. The Department of Energy's Advanced Manufacturing Office (AMO) also seeks individual input on performance metrics and identification of key problem sets to be addressed. The intent is to define critical crosscutting barriers that, if successfully addressed, could enable step change impacts beyond the current state of the art. Technology development should be focused on the gap between lab-scale development and deployment and scale-up. Specific goals include:

- To identify high value opportunities and manufacturing challenges to improve energy efficiency, reduce material /water use, and enable increased recycle & reuse.
- To discuss promising technologies and manufacturing systems that increase sustainability in manufacturing at the unit operations, facility and system level.
- To strategize how best to leverage R&D among the public sector, industry, and academia.
- To encourage discussion and networking among leaders in the field.

Description of the Opportunity:

Sustainable manufacturing[1] encompasses a wide range of systems issues, including energy intensity, carbon intensity, and use intensity. Energy considerations alone are insufficient to capture the full range of impacts. A more complete understanding can be gained by tracking how materials flow through manufacturing supply chains and where resources such as materials, water, and energy are used throughout product life cycles. Increased material efficiency will reduce the material use intensity of supply chains, and in turn will provide additional opportunities for energy efficiency.

Between 1975 and 2000, U.S. per capita materials consumption grew an estimated 23% and total material consumption grew an estimated 57%[2]. By 2005, the U.S. used nearly 20% of the global primary energy supply and 15% of globally extracted materials, equivalent to 8.1 gigatons (GT). At roughly 27

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[1] Numerous definitions for sustainable manufacturing are in use; all are concerned with the environmentally responsible production and use of manufactured goods. The U.S. Department of Commerce defines sustainable manufacturing as "the creation of manufactured products that use processes that are non-polluting, conserve energy and natural resources, and are economically sound and safe for employees, communities, and consumers." See http://www.trade.gov/competitiveness/sustainablemanufacturing/how_doc_defines_SM.asp. The U.S. Environmental Protection Agency defines sustainable manufacturing as "the creation of manufactured products through economically-sound processes that minimize negative environmental impacts while conserving energy and natural resources." See http://www.epa.gov/sustainablemanufacturing/ glossary.htm. The Organisation for Economic Co-operation and Development defines it as "managing operations in an environmentally and socially responsible manner." See http://www.oecd.org/innovation/green/toolkit/aboutsustainablemanufacturingandthetoolkit.htm.

[2] WRI. 2008. Material Flows in the United States – a Physical Accounting of the U.S. Industrial Economy. World Resource Institute, Washington, DC. ISBN 978-1-56973-682-1. Available at: www.wri.org/sites/default/files/pdf/material_flows_in_the_united_states.pdf.

metric tons (MT) per person, U.S. per capita material use is higher than most high-income countries.[3] Global demand for engineering materials has increased by a factor of four over that last half century and is projected to continue to increase with the growing global population. On the output side, the U.S. generated close to 2.7 GT of waste in 2000. U.S. waste generation has increased 26% since 1975, with a 24% increase in harmful waste products (radioactive compounds, heavy metals and persistent organic chemicals).

AMO's key interest in sustainable manufacturing is in technology development that improves energy-efficiency, reduces greenhouse gas emissions while improving the efficiency of material use throughout the manufacturing process. Technology development could focus on: 1) testing and demonstration of alternative feedstocks; 2) reduction of waste throughout the manufacturing process; 3) testing and demonstration of specific technology to improve reuse and recycling of materials, water and energy within the manufacturing process and at the end of product life; and 4) validation and deployment of the tools, processes and technologies to enable sustainable design and assessment. If successfully developed, sustainable manufacturing tools and processes could serve as models and benchmarks for the broader manufacturing sector – enabling greater adoption of sustainability towards a goal of zero waste manufacturing, including materials, energy and water.

Focus/Topics of Potential Efforts:

- ***Developing and Using Alternative/Sustainable Feedstocks:*** What are the opportunities, challenges and barriers to develop alternative and more sustainable feedstocks, such as waste streams from other processes/industries? As an example, terpene (an organic waste product from the wood processing industry) has been explored both as a replacement for petroleum-based fuel and as potential feedstocks for the bulk and fine chemicals sector What are the current barriers to wider implementation of such feedstocks? Other areas of interest include technology development needed to use renewable feedstocks as inputs to industrial processes, and specifically the manufacturing needs for implementation of new feedstocks.
- ***Reduction of Waste in Manufacturing Processes:*** Within various industrial sectors, there are opportunities to improve material efficiency within manufacturing processes. As an example, inefficient material production and manufacturing processes produce in-plant scrap and represent opportunities to improve material use intensity. In the aluminum and steel industries, for example, in plant scrap is reusable and often contains fewer contaminants than post-consumer scrap. However, equipment for processing these materials may not be available, costs can be high, and many manufacturing facilities lack the infrastructure to reuse in-plant scrap. Beyond metals, opportunities for substantial waste reduction exist in many sectors. Potential topics of interest would include technology development that would reduce scrap/waste

[3] Gierlinger, S., and Krausmann, F. 2012. The physical economy of the United States of America. Journal of Industrial Ecology. 16(3) 365-377.

production, develop processes that reuse manufacturing wastes (e.g., depolymerization), and minimize material usage within the manufacturing process.

- ***End-of-Life Management:*** Managing end-of-life (EOL) would ideally begin at the design stage to minimize waste and design for reuse/recycle. Current practices are varied across industrial sectors. In the certain sectors, EOL products are reused to a high degree. However, often that reuse is through down-cycling (i.e., recycling for use in a lower quality product or less demanding application). While down-cycling is preferable to landfilling or other disposal methods, developing new recycling technologies to retain the value of EOL materials are needed. Technologies that make product disassembly more efficient and improve reuse, recycling and remanufacturing are of interest. In addition to bulk single-material products, there are significant challenges in addressing reuse and recycling of multi-material products. As an example, there are EOL challenges with batteries used in electric and hybrid vehicles. As deployment of these batteries increases, technologies need to be developed to recover, reuse and recycle EOL materials.
- ***Materials, Water and Energy Management:*** The concept of "reduce, reuse, and recycle" has been at play for many years, with recycling at the forefront of related efforts. Reducing material use, however, has a large potential to reduce energy consumption early in the supply chain and in product manufacturing. Technologies that enable more efficient use of raw materials are of interest. For example, technologies that increase the useful lifespan of products through improved durability, use of lighter weight materials and overall products. Other areas for consideration include: supply chain and material sourcing; technologies to improve material efficiency within the manufacturing supply chain; reduction in bill of materials; and decentralized production of hazardous/toxic/harmful chemicals.
- **Sustainable Design and Decision-Making:** For the private sector, it can be a challenge to properly calculate the benefit of investing in more sustainable technologies. Benefits of those investments do not always manifest as increased profit. Additionally, companies do not always bear the costs of unsustainable decisions. As an example, water discharged from a manufacturing facility may meet regulations – but the change in temperature or pH can still negatively impact the ecosystem. While certain companies have made sustainability part of their company values, others find it challenging to properly assess sustainability ("triple bottom line"). What are the barriers to improve sustainable decision-making? Design guidelines and tools are needed to facilitate sustainability accounting and decision-making, incorporating life-cycle analysis (including energy), materials minimization in manufacturing design and production, and design for disassembly.

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Further Background

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