Improving Energy Efficiency at Petrochemical Facilities

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1. Introduction

As U.S. manufacturers face an increasingly competitive global business environment, they seek out opportunities to reduce production costs without negatively affecting product yield or quality. Uncertain energy prices in today's marketplace negatively affect predictable earnings, which are a concern, particularly for the publicly traded companies in the petrochemical industry. Improving energy efficiency reduces the bottom line of any petrochemical plant. For public and private companies alike, increasing energy prices are driving up costs and decreasing their value added. Successful, cost-effective investment into energy efficient technologies and practices meets the challenge of maintaining the output of a high-quality product despite reduced production costs. This is especially important, as energy-efficient technologies often include "additional" benefits, such as increasing the productivity of the company and reducing the emission of greenhouse gases.

Energy use is also a major source of emissions in the petrochemical industry making energy-efficiency improvement an attractive opportunity to reduce emissions *and* operating costs. Energy efficiency should be an important component of a company's environmental strategy. End-of-pipe solutions can be expensive and inefficient while energy efficiency can be an inexpensive opportunity to reduce criteria and other pollutant emissions. Energy efficiency can be an efficient and effective strategy to work towards the so-called "triple bottom line" that focuses on the social, economic, and environmental aspects of a business[1]. In short, energy efficiency investment is sound business strategy in today's manufacturing environment.

Voluntary government programs aim to assist industry to improve competitiveness through increased energy efficiency and reduced environmental impact. ENERGY STAR→, a voluntary program managed by the U.S. Environmental Protection Agency (EPA), highlights the importance of strong and strategic corporate energy management programs. ENERGY STAR provides energy management tools and strategies for successful corporate energy management programs. This course describes research conducted to support ENERGY STAR and its work with the petrochemical industry. This research provides information on potential energy efficiency opportunities for companies within the petrochemical sector. ENERGY STAR can be contacted through www.energystar.gov for additional energy management tools that facilitate stronger energy management practices in U.S. industry.

This Energy Guide assesses the energy efficiency opportunities for the petrochemical industry. The U.S. chemical industry is the largest chemical industry in the world. The sector employs nearly 800,000 people and generates product shipments and value added of $416 billion and $295 billion respectively. The petrochemical industry - defined in this Energy guide as facilities involved in the production of basic petrochemicals, other organic chemicals and plastic materials and resins – has a share of about 20% in the number of employees and value added and a share of 30% in the product shipments of the total chemical industry.

[1] The concept of the "triple bottom line" was introduced by the World Business Council on Sustainable Development (WBCSD). The three aspects of the "triple bottom line" are interconnected as society depends on the economy and the economy depends on the global ecosystem, whose health represents the ultimate bottom line.

Energy is a very important cost factor in the chemical industry in general and the petrochemical industry is even more energy intensive than other sub-sectors within the chemical industry. The petrochemical industry is responsible for 70% of the chemical industry's expenditures on fuels and 40% of the expenditures on electricity. The costs of energy and raw materials (which are to a very large extent derived from fossil fuels) are roughly $2/3^{rd}$ of the total value of shipments of the petrochemical industry. Because energy is such an important cost factor, energy efficiency is a very important opportunity for cost reductions.

The Guide first describes the trends, structure and production of the industry in the United States It then describes the main production processes. Following, it summarizes energy use in the petrochemical industry and its main end uses. Finally, it discusses energy efficiency opportunities for U.S. petrochemical production facilities. The Guide focuses on measures and technologies that have successfully been demonstrated in individual plants in the United States or abroad, but that can still be implemented in other plants. Because the petrochemical industry is an extremely complex industry, this Guide, by definition, cannot include all opportunities for all petrochemical plants. Although new technologies are developed continuously (see e.g., Martin et al., 2000), the Guide focuses on practices that are proven and currently commercially available.

This course aims to serve as a guide for energy managers and decision-makers to help them develop efficient and effective corporate and plant energy management programs through information on new or improved energy-efficient technologies.

2. The U.S. Petrochemical Industry

The United States has the world's largest chemical industry. Within the chemical industry, more than 70,000 diverse compounds are produced with production volumes ranging from a few grams to billions of pounds. Given the diversity of the industry, it can be useful to subdivide the chemical industry into various subcategories. One possible division is the division between the organic and inorganic chemicals industry. In the inorganic chemical industry, chemical products are produced from non-carbon elements taken from the earth such as phosphor (phosphoric acid, phosphates), nitrogen (nitrogenous fertilizers) and chlorine. In the organic chemical industry, hydrocarbon raw materials for the chemical industry are used to produce about 10 base products (that are used as the basis for a multitude of products). Approximately 95% of organic products today are produced from oil and natural gas derived raw materials, with a declining share being produced from coal and an increasing but still very small share from biomass raw materials. The base materials are further processed to various intermediates and final products (e.g., polymers, solvents) by introducing functional groups to the base materials. A figure with the various pathways from basic hydrocarbons to end use polymers is provided in Chapter 3.

The North American Industry Classification (NAICS) distinguishes seven 4-digit sub-sectors of the chemical industry:

3251 Basic chemical manufacturing
3252 Resin, synthetic rubber, and artificial synthetic fibers and filaments manufacturing
3253 Pesticide, fertilizer and other agricultural chemical manufacturing
3254 Pharmaceutical and medicine manufacturing
3255 Paint, coating, and adhesive manufacturing
3256 Soap, cleaning compound, and toilet preparation manufacturing
3259 Other chemical product and preparation manufacturing

Within this 4-digit industry classification, seventeen 5-digit and 34 6-digit industrial sub-sectors are distinguished (Appendix A). This Guide focuses on the production of large volume, energy-intensive basic and intermediate *organic* chemicals including the manufacturing of the large volume plastic materials and resins. The Guide excludes the production of fertilizers and pesticides, industrial gases, inorganic chemicals, pharmaceuticals, paints, soaps and other small volume fine chemicals. The industries on which this guide focuses are classified into the following three 6-digit industries in the NAICS classification:

325110 Petrochemical manufacturing

This industry comprises establishments primarily engaged in (1) manufacturing acyclic (i.e., aliphatic) hydrocarbons such as ethylene, propylene, and butylene made from refined petroleum or liquid hydrocarbon and/or (2) manufacturing cyclic aromatic hydrocarbons such as benzene, toluene, styrene, xylene, ethyl benzene, and cumene made from refined petroleum or liquid hydrocarbons.

325199 All other basic organic chemical manufacturing

This industry comprises establishments primarily engaged in basic organic chemical products (except aromatic petrochemicals, industrial gases, synthetic organic dyes *and pigments, gum and wood chemicals, cyclic crudes and intermediates, and ethyl alcohol).*

325211 Plastic material and resin manufacturing

This industry comprises establishments primarily engaged in 1) manufacturing resins, plastics materials, and non-vulcanizable thermoplastic elastomers and mixing and blending resins on a custom basis, and/or 2) manufacturing non-customized synthetic resins.

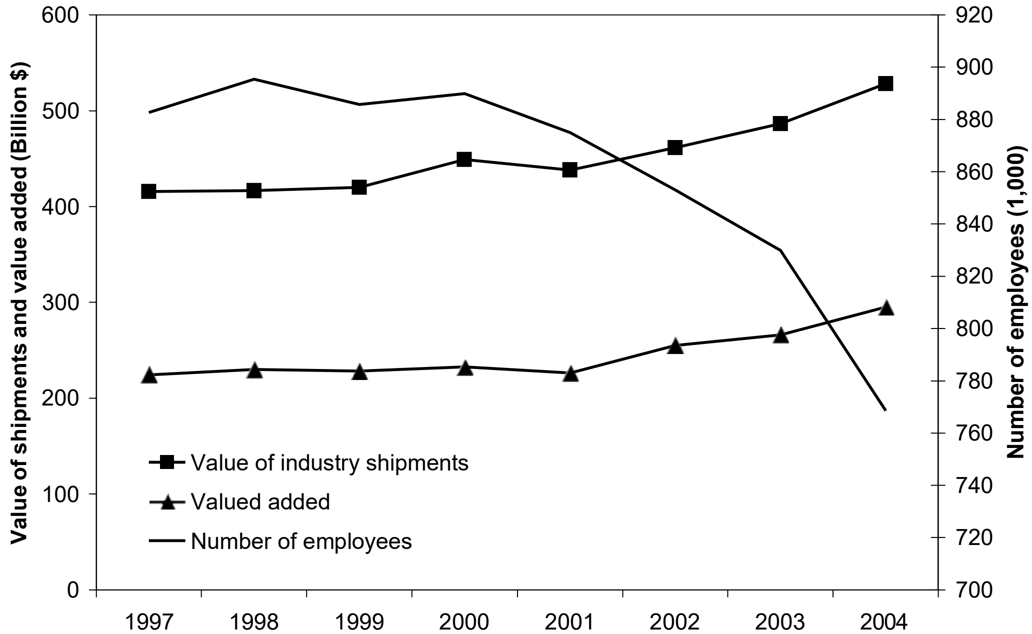
The classification of companies into one of these three NAICS categories is by no means straightforward as a result of the vertical integration of activities on the same site. A company only operating a steam cracker and selling the steam cracker products (ethylene, propylene) will be classified within the petrochemical industry. Another company, operating a steam cracker and converting the main products into basic polymers (polyethylene and polypropylene) will be classified with the resin and synthetic rubber manufacturing industry. In the statistical overviews, this Energy Guide will focus mainly on the sum of the three sectors.

It should further be noted that, although the focus of this guide is on the sectors mentioned above, many of the energy efficiency improvement opportunities mentioned also apply to other parts of the organic (and inorganic) chemical industry. In fact, process integration is an important characteristic of the worldwide chemical industry and some of the companies classified in the sectors cited above are also active in the production of many other organic and inorganic chemicals. As a result, measures such as improvement of energy management systems do apply not only to the petrochemical industry. Several industry examples included in this course are taken from other sub-sectors of the chemical industry.

2.1 Economic Trends for the Total Chemical Industry

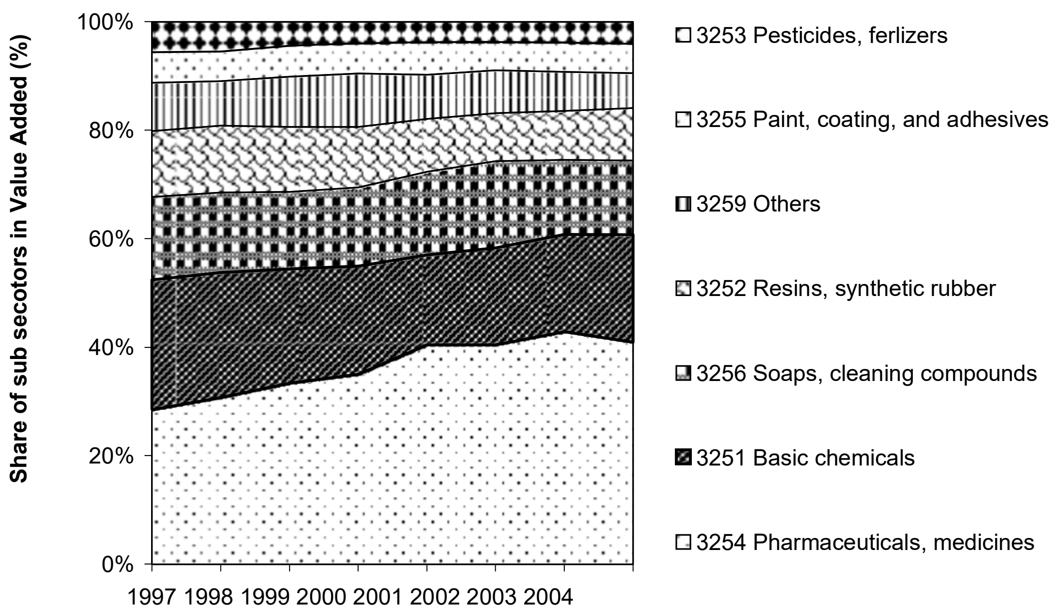
In 2004, the U.S. chemical industry generated $528 billion in product shipments and created a value added of $295 billion (see Figure 2.1). These numbers increased from $416 billion (shipments) and $225 billion (value added) in 1997, an increase of 27 and 31% respectively. The industry creates this value added with a declining number of employees (down from 883,000 in 1997 to 769,000 in 2004). The total number of establishments in 2004 was 13,247 (U.S. Census Bureau, 2006). This number has been quite stable in recent years (13,595 in 1998). Of the 7 four-digit sub-sectors distinguished in the NAICS, the largest and increasing share of value added is created by the pharmaceuticals and medicines sector (30% in 2004), followed by the basic chemical sector (26%) (see Figure 2.2). The share of the sub-sectors in the total energy consumption of the chemical industry is very different compared to the share in total value added and industry shipments as a result of significantly differing energy intensities (see Chapter 4).

Figure 2.1 Value of shipments, value added and number of employees in the U.S. chemical industry.



Source: U.S. Census Bureau (2003 and 2005)

Figure 2.2 Value added by sub-sector of the U.S. chemical industry.



Source: U.S. Census Bureau (2003 and 2005)

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