

## Chapter 6

# Sustainable Process Integration in the Petrochemical Industries

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### ABSTRACT

*The petrochemical industry has a substantial impact on the environment through the use of large quantities of natural resources (mass and energy) and discharge of wastes into the environment. Process integration offers a powerful framework for the sustainable development of the petrochemical through conservation of mass and energy and synergism among the different building blocks in the supply chain. The chapter provides an overview of process integration basics and tools that can be used to enhance the performance of the petrochemical industry. The chapter also describes the key building blocks of the petrochemical supply chain and how they may be integrated. Finally, the chapter describes key drivers and opportunities of process integration within individual petrochemical plants, among various petrochemical facilities, and the relationship to the existing refining infrastructure.*

### 1. INTRODUCTION TO SUSTAINABLE DESIGN THROUGH PROCESS INTEGRATION

The petrochemical industry involves the usage of substantial quantities of natural resources in the form of raw materials, solvents, water, and energy. Furthermore, the impact of this industry on the environment is substantial. Industry is now launching various initiatives towards sustainable development. One definition of sustainable development emerged from the “Brundtland Report” of the 1987 World Commission on Environment and Development (WCED, 1987) which characterized sustainable development as “meeting the needs of the present without compromising the ability of future generations to

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meet their own needs.” Another definition was provided by Sikdar (2003): “sustainability occurs when we maintain or improve the material and social conditions for human health and the environment over time without exceeding the ecological capabilities that support them”. For the petrochemical industry, sustainable development includes enhancing mass and energy efficiency, mitigating pollution, and increasing profitability. El-Halwagi (2012) defines sustainable design as: “the design activities that lead to economic growth, environmental protection, and social progress for the current generation without compromising the potential of future generations to have an ecosystem which meets their needs. The following are the principal objectives of a sustainable design:

- Resource (mass and energy) conservation;
- Recycle/reuse;
- Pollution prevention;
- Profitability enhancement;
- Yield improvement;
- Capital-productivity increase and debottlenecking;
- Quality control, assurance, and enhancement;
- Process safety.

As a result of the complex interaction among the different building blocks in the petrochemical industry and the need to reduce the associated usage of mass and energy resources and environmental impact, there is a need to develop and apply a holistic approach to improving the design and operation, enhancing mass and energy efficiency, and mitigating negative impact on the environment. Process integration offers a definitive and powerful framework for the sustainable design and optimization of the petrochemical industry and supply chains. Process integration is defined as “a holistic approach to process design, retrofitting, and operation which emphasizes the unity of the process” (El-Halwagi, 1997). Process integration may be classified into three branches: mass integration for the tracking and optimization of chemical species, energy integration for the transfer, transformation, and optimization of different forms of energy, and property integration for the functionality-based design of industrial processes. For a detailed description of the basics, methodologies, tools, and applications of process integration, the reader is referred to literature (e.g., El-Halwagi and Foo, 2014; El-Halwagi, 2012; Foo et al., 2011; Nouredin, 2011; Majozi, 2010; Rossiter, 2010; Foo, 2009; Kemp, 2007; El-Halwagi, 2006; Smith, 2005; El-Halwagi et al., 2004; Dunn and El-Halwagi, 2003; Hallale, 2001; El-Halwagi and Spriggs, 1998; El-Halwagi, 1997; and Shenoy, 1995).

## **2. OVERVIEW OF THE PETROCHEMICAL INDUSTRY**

The chemical industry and in particular, petrochemicals, continues to play an important role in the advancement of other major industries such as construction, automotive, packaging, and consumer goods. The chemical industry primarily provides raw materials for other industrials and not directly to consumers, and thus is sometimes referred to as the hidden industry. This means that the chemical business is strongly influenced by weakness or strength in those industries. The rise of the petrochemical industry in the 20<sup>th</sup> century was strongly driven by the availability of feedstock, advances in chemistry and technology, the demand for new products and alternative processing pathways.

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