# The Economic Feasibility of Recycling

## A Case Study of Plastic Wastes

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*To my family*

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# About the Author

**T. Randall Curlee** is an economist and research staff member in the Energy and Economic Analysis Section within the Energy Division at the Oak Ridge National Laboratory. Dr. Curlee has published several articles and reports on various aspects of plastics recycling. He has also published in the areas of oil vulnerability and strategic stockpiling, oil pricing, uranium markets, and the market penetration of new materials and technologies.

Dr. Curlee received his B.S. degree in economics from the University of Tennessee in 1976. He was awarded the M.S. and Ph.D. degrees in economics from Purdue University in 1978 and 1981, respectively.

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# 1
# Introduction and Overview

## INTRODUCTION

A significant amount of work has been done in recent years to address the problems, as well as opportunities, posed by the production and accumulation of plastic wastes. However, the vast majority of work has focused on technological questions and has largely neglected the economic and institutional incentives and barriers that may have a pronounced impact on the degree to which recycling technologies are ultimately adopted in the marketplace. This book addresses the problems and opportunities associated with plastics recycling from an economic perspective, and reviews numerous economic and institutional factors that have not heretofore been studied—factors that may largely determine whether future plastic wastes will be disposed of or recycled.

The increased interest in plastics recycling has arguably resulted from three important trends. First, the production and use of plastic resins in the United States has more than quadrupled during the past two decades. Plastics now compose approximately six percent of the typical municipal waste stream and projections indicate that this percentage will increase during the coming decade. Virtually every market segment now uses plastics in some form as technological innovations result in new plastic resins and composites with widely varying physical and chemical properties. Furthermore, it is generally agreed that most markets will increase their usage of plastic resins in coming years as the properties and cost competitiveness of more conventionally used materials are surpassed by those of existing and forthcoming plastics.

Second, while the relative price of plastic resins and materials has decreased in relation to the prices of metals and paper products during recent years, resin prices have increased dramatically in absolute terms.[1] The price of plastics rose sharply following the drastic petroleum price increases of 1973–74 and 1978–79. (Petroleum and natural gas are, of course, the primary raw materials used in the production of plastic resins.) The value of the plastics entering the waste stream has therefore been perceived to have risen in accordance with increases in the prices of virgin resins. Further, as the prices of oil and other traditional energy sources have escalated, the energy content in plastic wastes, which is roughly equivalent to that of coal on a per pound basis, has become increasingly valuable.

Third, growing concern about the quality of the environment has led to more restrictive disposal regulations. While there is disagreement about the extent to which plastics pose environmental problems in waste disposal, there is agreement that waste disposal is, in general, becoming more expensive. From an economic perspective, these escalating disposal costs make plastic waste recycling more viable. And to the extent that plastic wastes may be harmful to the environment, the public has an incentive to reduce the volume of plastics entering the disposal stream.

In response to these trends, numerous studies and research and development projects have been undertaken to address the technological problems posed by the recycling of plastic wastes. A flurry of activity occurred in the early 1970s to develop technologies that could separate plastics from other types of waste and recycle that waste to produce new plastic products, retrieve basic chemicals from the waste, or retrieve the heat content of the waste. Technologies have been developed that utilize plastic wastes to produce products as diverse as fenceposts and fuel oil. In many cases these technological efforts have been successful and several recycle technologies are now being tested or are fully operational. Many claim to be economically viable. Moreover, work continues on new processes that may increase the quality and reduce the cost of products derived from plastic wastes.

However, at this time the technologies that are available to recycle plastics have met little success in penetrating their potential markets, especially in the United States. The quantity of plastic waste that is currently recycled is minuscule when compared with the total quantity of plastic waste currently being produced. Further, with the exception of a few isolated market segments, there is little current movement toward the adoption of practices to recycle plastics on a large scale. There is an increasing recognition that plastics recycling is an extremely complicated issue, not only from a technological perspective but also from economic and institutional perspectives.

The primary purpose of this book is to identify and study the numerous economic and institutional incentives and barriers that impact on the decision to recycle or dispose of plastic wastes. These incentives and barriers are addressed from the perspective of individuals and firms that must make a decision to either recycle or dispose of plastic wastes and from the perspective of the general public that must through legislation and regulations encourage recycling, discourage recycling, or be neutral on the issue. An overview of the purposes, scopes, and limitations of the analyses presented in subsequent chapters that address these and other issues is the topic of the following section.

## OVERVIEW OF SUBSEQUENT CHAPTERS

*Chapter 2.* While it is not the purpose of this book to present a detailed or definitive discussion of the various technological issues that are relevant to plastics recycling, it is imperative that a minimal understanding of the technological issues be obtained in order to understand the intricacies of the economic and institutional issues that may impact on the decision to recycle. Chapter 2 contains a relatively nontechnical discussion of these technological issues. There are three focuses of the discussion: a) the various types of plastics and how the characteristics of different resins impact on their recyclability; b) the different types or groups of technologies that can be used to dispose of or recycle plastic wastes and some specific examples of technologies within each technology group; and c) the environmental impacts of disposing or recycling plastics by using the various available technologies.

One of the major, if not the major, technological problem to be faced in recycling plastic wastes is the diversity of the physical and chemical characteristics of the numerous resins that are called "plastic". There are two main types of plastics—thermoplastics, which can be repeatedly reformed by softening or melting under heat and pressure, and thermosets, which cannot be remelted once their interlinking molecular bonds are formed. Obviously, the characteristics of thermosetting resins make those resins much more difficult to recycle than thermoplastic resins. Further, within each major group of plastic resins, the physical and chemical characteristics of the different resins vary widely. (These specific characteristics are addressed in more detail in Chapter 2 and in Appendix A, which summarizes the characteristics and typical uses of some of the major thermoplastic and thermoset plastic resins.) While one thermoplastic may melt at, for example, 150°F, another thermoplastic may have a melting temperature in excess of 500°F. Moreover, it is difficult to predict how the physical characteristics of a mixture of different resins will vary from the characteristics of the resins when used individually. Therefore, in no sense can plastic resins be thought of as being uniform. Different resins vary in characteristics and properties as much as, for example, steel differs from aluminum. These heterogeneous characteristics of resins severely limit the types of recycling that are technically feasible and greatly complicate the discussion of the economic feasibility of plastics recycling.

The recycling of plastic wastes is further complicated in that a plastic resin in one waste stream is not identical to the same resin in another waste stream. As will become clearer in Chapter 2, a major technical constraint to the recycling of plastic wastes is the form in which that waste enters the waste stream. While significant technical progress has been made toward separating plastics from other wastes, it is generally recognized that once a plastic enters the municipal waste stream, it is technically very difficult and not economically viable to separate that plastic from other municipal wastes. Therefore, a major key to recycling plastic waste, at least in a relatively uncontaminated form, is our ability to collect and process that waste before it enters the municipal waste stream. Obviously this ability depends on the product in which the waste resin appears and how that product is typically disposed of. The collection possibilities and therefore the recycling potential for a thermoplastic waste in, for example, the form of a returnable soft drink bottle are vastly different from the possibilities for the same resin when it appears in the form of consumer product packaging, which is extremely difficult to divert from the municipal waste stream.

Another technical complication that distinguishes the issue of plastics recycling from other widely recycled materials—such as steel, aluminum, and copper—is the various ways plastics can be recycled. Unlike metal recyclers that take metal scrap in a contaminated form and basically reduce the contamination to a level acceptable for the intended use, plastics recyclers have several alternatives. Recycling technologies are usually discussed in one of four major categories. Primary recycling is the processing of waste into a product with characteristics similar to those of the original product. The plastics industry has historically recycled much of the waste that occurs during resin production, fabrication, conversion, and product assembly in a primary sense. However, the primary recycling of plastic wastes does not allow for any significant waste contamination and therefore is not applicable for more contaminated manufacturing wastes (sometimes referred to as manufacturing nuisance plastics) and virtually all types of postconsumer plastic wastes. For the most part, this book is not concerned with the primary recycling of clean manufacturing waste, but rather focuses on those manufacturing and postconsumer plastic wastes that have historically been disposed of by landfill or incineration.

Secondary recycling is the processing of plastics waste into products with characteristics that are inferior to those of the original product. As is discussed in some detail in Chapter 2, there are numerous technologies that are available to recycle thermoplastic wastes into products such as drainage pipes and construction materials similar to wood products. The use of these technologies is predominantly limited by the percentage of the total waste that is composed of thermoplastics. This technological constraint reemphasizes the importance of collecting plastic wastes independently of other municipal wastes or having the capability to economically separate plastics from other waste materials. There is also some discussion in the general literature of recycling thermo-

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