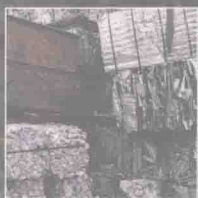


*McGraw-Hill*

# THE MCGRAW-HILL RECYCLING HANDBOOK

SECOND EDITION



HERBERT F. LUND

---

# **THE MCGRAW-HILL RECYCLING HANDBOOK**

---

**Herbert F. Lund, Editor in Chief**

**Second Edition**

**McGRAW-HILL**

**New York San Francisco Washington, D.C. Auckland Bogotá  
Caracas Lisbon London Madrid Mexico City Milan  
Montreal New Delhi San Juan Singapore  
Sydney Tokyo Toronto**

## Library of Congress Cataloging-in-Publication Data

The McGraw-Hill recycling handbook / Herbert F. Lund, editor in chief. — 2nd ed.

p. cm.

Includes index

ISBN 0-07-039156-4

1. Recycling (Waste, etc.) 2. Recycling (Waste, etc.)—United States. I. Lund, Herbert F.  
TD794.5 .M397 2000  
363.72'82—dc 21

00-028382

# McGraw-Hill

A Division of The McGraw-Hill Companies



Copyright © 2001 by The McGraw-Hill Companies, Inc. All rights reserved. Printed in the United States of America. Except as permitted under the United States Copyright Act of 1976, no part of this publication may be reproduced or distributed in any form or by any means, or stored in a data base or retrieval system, without the prior written permission of the publisher.

1 2 3 4 5 7 8 9 0 DOC/DOC 0 6 5 4 3 2 1 0

ISBN 0-07-039156-4

*The sponsoring editor for this book was Scott Grillo and the production supervisor was Pamela A. Pelton. It was set in Times Roman by Ampersand Graphics, Ltd.*

Printed and bound by R. R. Donnelley and Sons, Co.



This book was printed on recycled, acid-free paper containing a minimum of 50% recycled de-linked fiber.

McGraw-Hill books are available at special quantity discounts to use as premiums and sales promotions, or for use in corporate training programs. For more information, please write to the Director of Special Sales, Professional Publishing, McGraw-Hill, Two Penn Plaza, New York, NY 10121-2298. Or contact your local bookstore.

Information contained in this work has been obtained by The McGraw-Hill Companies, Inc. ("McGraw-Hill") from sources believed to be reliable. However, neither McGraw-Hill nor its authors guarantee the accuracy or completeness of any information published herein and neither McGraw-Hill nor its authors shall be responsible for any errors, omissions, or damages arising out of use of this information. This work is published with the understanding that McGraw-Hill and its authors are supplying information but are not attempting to render engineering or other professional services. If such services are required, the assistance of an appropriate professional should be sought.

---

# FOREWORD

---

Recycling is happening almost everywhere you turn. It is roaring through the halls of government and business like a freight train and there is no stopping it.

Cities and states across the country are passing recycling laws as fast as they can. As this is written, virtually every state in the country has some kind of recycling requirement on its books. Homeowners and businesses alike are now incorporating recycling into their day-to-day activities at an increasing rate.

Recycling is destined to become a permanent part of how we manage waste in this country, but it will take some patience on our part to get there. We will not turn around decades of past practices overnight; nor will we as a society embrace without qualification a practice that, in the end, does not deliver what we wanted.

Laws are now on the books, programs are being put in place, industry is making major investments in plants and equipment to process and reuse the materials collected for recycling. Markets are being developed and habits are slowly being changed. This is all for the good—but it will take some time and the expenditure of precious resources. But the basic system is coming together, and if we give it time, recycling will assume a permanent and major role in our lives.

Of course, this all presumes that we do it well, that the programs we put in place do what they are supposed to do. The recycling landscape has evolved so rapidly in the past few years, that keeping up with the changes is a major challenge. That is where this valuable new book comes in. In *The McGraw-Hill Recycling Handbook*, Herbert Lund has put together a collection of information from experts that covers all aspects of recycling in this country. While primarily aimed at all professionals responsible for planning and operating recycling programs, this book can be of enormous help to local government officials and to the business community as well.

From yard waste to TV sets, from setting realistic recycling goals to setting up reporting systems, this volume provides a comprehensive look at the state of recycling today and where it is likely to be tomorrow.

As a nation, we are moving to make recycling a permanent part of our lives. This Handbook can help make that transition as efficient as possible.

*William D. Ruckelshaus*  
Former Chairman and CEO,  
Browning-Ferris Industries, Inc.  
and Former EPA Administrator

---

# PREFACE TO THE SECOND EDITION

---

The original *McGraw-Hill Recycling Handbook* was published in 1993. Both Bob Esposito, Executive Editor in the Professional Books Division, and I felt there have been numerous improvements and sufficient changes in the recycling field to warrant a new Second Edition. Not only have there been improvements but the whole field has grown up from immature infancy to a booming, sophisticated new industry.

In this Second Edition, we not only keep you up-to-date with current improvements and changes, but we look ahead for outstanding new developments. For instance, in the field of separating colored glass, we found a European-American new automatic technology that uses worthless mixed cullet and achieves a 70% separation. Also looking to the future, we present how to best apply computers to recycling operations. Also, although municipal solid wastes (MSW) combustible ash may or may not be economically recycled at present, John Booth, Director of Engineering, Solid Waste Authority of Palm Beach County, Florida reviews the economics and looks into the future.

Some of the new important handbook additions are recycling electronic devices, mercury-containing devices and lamps, textiles, and carpeting in the expanded materials section. In the recycling operations section, besides the role of computers, we offer an intense new chapter on recycling at large commercial facilities, with particular emphasis on theme parks and sports arenas. Our rules and regulations coverage has been updated, stressing recycling issues and followed by state-by-state information. Under collection operations, we have included the latest on weight-based systems.

There has been increasing interest in the Spanish Edition of the handbook. For this reason and due to more recycling developments abroad, we have added a significant new section on Recycling in Other Countries. EPA, The Office of Solid Waste, has updated Appendix A, "Recycling Information and Sources" for back-of-book references and contacts.

And as with the original 1993 handbook, my wife Belle and I have updated the Glossary and the comprehensive cross-referenced index to make sure this Second Edition continues to be your indispensable desktop reference to recycling.

*Herb Lund*

---

# CONTENTS

---

**Foreword ix**

**Preface to the Second Edition xi**

## **SECTION I THE BASICS OF RECYCLING**

### **Chapter 1 Recycling Overview and Growth 1.1**

*Joseph A. Ruiz, Jr.*

### **Chapter 2 Legislative Policies and Evaluations 2.1**

*Michelle Raymond*

### **Chapter 3 Characterization of Waste Streams 3.1**

*David S. Cerrato*

### **Chapter 4 Setting Recycling Goals and Priorities 4.1**

*J. Frank Bernheisel*

### **Chapter 5 Separation and Collection Systems 5.1**

*Abbie (Page) McMillen*

**with a special section on Volume- and Weight-Based  
Collection Rates by Lisa A. Skumatz**

### **Chapter 6 Processing Facilities for Recyclable Materials 6.1**

*Thomas M. Kaczmarek, William P. Moore,  
and John D. Booth*

### **Chapter 7 Market Development: Problems and Solutions 7.1**

*Gregg D. Sutherland*

### **Chapter 8 Financial Planning and Program Development 8.1**

*Robert Hauser, Jr.*

### **Chapter 9 The Psychology of Recycling 9.1**

*Penny McCornack*

**SECTION II RECYCLING MATERIALS****Chapter 10 Electronic Devices 10.1***Joseph C. Yob, Jr.***Chapter 11 Paper 11.1***Tom Friberg, Lisa Max, and Lynn M. Thompson***Chapter 12 Aluminum Cans 12.1***Durene M. Ayer***Chapter 13 Glass Beverage Bottles 13.1***Tammy L. Hayes, Anthony Lame, and Richard Lehman***Chapter 14 Plastics 14.1***Tim Buwalda***Chapter 15 Steel Recycling 15.1***Gregory L. Crawford***Chapter 16 Carpeting 16.1***Lynn Preston***Chapter 17 Textiles 17.1***Bernard Brill***Chapter 18 Tires 18.1***Michael Blumenthal***Chapter 19 Batteries 19.1***Ann Patchak Adams***Chapter 20 Construction and Demolition  
Debris 20.1***Edward L. von Stein***Chapter 21 Household Hazardous Wastes 21.1***Buff Winn***Chapter 22 Mercury-Containing Devices  
and Lamps 22.1***Raymond P. Jackman and John L. Price*

### **SECTION III RECYCLING FACILITIES AND EQUIPMENT**

- Chapter 23 Transfer Stations 23.1**  
*R. Christian Brockway*
- Chapter 24 Materials Recovery Facilities 24.1**  
*Thomas D. Knox and R. Christian Brockway*
- Chapter 25 Integrating Recycling with Landfills  
and Incinerators 25.1**  
*Ernest H. Ruckert, III*
- Chapter 26 Processing Yard Waste 26.1**  
*Richard J. Hlavka*
- Chapter 27 Collection Vehicles and Equipment 27.1**  
*Bob Graham*
- Chapter 28 Processing Equipment 28.1**  
*Kenneth Ely, Jr.*

### **SECTION IV RECYCLING OPERATIONS**

- Chapter 29 Recycling Program Planning and  
Implementation 29.1**  
*Thomas A. Jones, Jr. and Karen Lukens*
- Chapter 30 Public Awareness Programs 30.1**  
*Joseph C. Barbagallo*
- Chapter 31 Training Personnel and Managers 31.1**  
*Betty Muise*
- Chapter 32 Recycling Program Considerations,  
Decisions, and Procedures 32.1**  
*Barbara J. Stevens*
- Chapter 33 Data Collection, Cost Control, and  
the Role of Computers in the Recycling  
Industry 33.1**  
*Daniel E. Strobridge, Frank G. Gerlock, and Richard Hlavka*



**Chapter 34 Quality Control Monitoring for  
Recyclable Materials 34.1**

*Steven A. Katz and Scott W. Spring*

**Chapter 35 Recycling at Large Commercial  
Facilities 35.1**

*Cyndie Eckman*

**SECTION V CASE HISTORIES**

**Chapter 36 Case Histories 36.1**

*Lisa Wagner Haley, Kevin McCarthy,  
and David C. Sturtevant*

**SECTION VI RECYCLING IN OTHER COUNTRIES**

**Chapter 37 Recycling in Other Countries 37.1**

*Herbert F. Lund, Editor in Chief*

**Appendix A Recycling Information and Sources A.1**

*Terry Grogan and Herbert F. Lund*

**Appendix B Glossary B.1**

*Herbert F. Lund and Belle Lund*

**Appendix C Abbreviations C.1**

**Index I.1**

---

# CHAPTER 1

---

# RECYCLING OVERVIEW AND GROWTH

---

**JOSEPH A. RUIZ, JR.,**  
*Former Vice President, Attwoods, Inc.*  
*Coconut Grove, Florida*

---

## **RECYCLING DEFINED**

---

### **The Recycling Perplexity**

Recycling? This is a seductive word to the environmentally aware among us. But what is it? What does it mean? What is it all about? Who does it? Why should I? These questions seem almost endless. Some have simple answers. Many answers are a part of a much more complex issue. Many more are yet unresolved and others are only now evolving. Just addressing the question of definition becomes an evermore complex issue as almost every governmental entity, industrial and commercial trade organizations, professional associations, academics, and practitioners attempt to define what it is. Because each has a different perspective and goal, each has a slightly different definition. Even a dispassionate search for a bias-free definition is difficult perhaps because of the circular nature of the subject.

When does the cycle begin or end? Does it ever? Does paper recycled for use as a raw material in making boxboard constitute a virgin material? What about the boxboard trimmings that were made from recycled materials? Are they waste again? If so, were they ever recycled? Perhaps a better understanding of how and why we got here can make any current definition more meaningful.

### **What It Is Today**

Recycling today is, and must be understood as, a solid waste management strategy. A method of solid waste management equally useful as landfilling or incineration and environmentally more desirable. Today it is clearly the environmentally preferred method of solid waste management.

### **The Beginning**

Early humans did not have a solid waste management strategy per se simply because the hunter-gatherer existence did not require one. Never staying in one place long enough to

accumulate any significant amount of solid waste, as well as a need to utilize scarce resources to their highest degree, probably did not create any concern or action. However, as humans began to settle in permanent communities with higher concentrations of waste-producing individuals and activities, the need for waste management became evident. Although this occurred around 10,000 B.C. in some places, it occurred much later in others and remains much less a concern in the less populated and more rural areas of the planet even today.

By 500 B.C. Athens organized the first municipal dump in the western world, and scavengers were required to dispose of waste at least 1 mile from city walls. This imperative continued from place to place, going forward and backward relative to the desires and ability of governments. During the middle ages waste disposal continued to be an individual responsibility commensurate with the lack of enlightened authority by government.

In 1388 the English Parliament banned waste disposal in public waterways and ditches. A few short years later in 1400 garbage was piled so high outside the Paris gates that it interfered with the defense of the city. These examples are cited because they indicated a desire on the part of government to assume responsibility for this element of the health and safety of the community primarily when other responsibilities such as drainage and defense were involved. This growth in governmental concern for health and safety with regard to waste disposal led to additional regulations and operations. By the 1840s the western world began to enter the "Age of Sanitation" as filthy conditions began to be seen as a nuisance that the public demanded government to resolve. Sanitarians employed by government primarily to deal with sewage disposal increasingly turned their attention to solid wastes.

Government's increasing assumption of solid waste management soon led to systematic approaches including the "destructor," an incineration system in Nottingham, England, in 1874. America's first municipal incinerator on Governor's Island in New York was built in 1885.

Government response continued to include a wide variety of innovative programs designed to address both specific elements of the solid waste stream as well as the broad brush approach of dumps and incinerators. Municipalities cleaned streets and sanitary engineers invented new technologies to reduce costs and volume. Fats and oils were recovered for reuse in manufacturing soap and candles. Incinerators generated steam for power and heat. Rags were increasingly recycled for use in making paper, and the inherent value of metals was always enhanced during war times to a sufficient level to promote public recycling programs. But environmental concerns were generally limited beyond the next hill, out at sea and out of sight. Ocean dumping and open space outside of the urban areas continued to be both environmentally acceptable and economical.

## **Recycling in Modern Times—Awakening to Solid Waste Responsibilities**

Only after World War II did fast-growing populations, greatly enhanced scientific understanding of the environment, and later the concept of finite resources combine to truly afford an opportunity for a conscious examination of the detrimental nature of land or ocean disposal practices. A rapid expansion in understanding the long-term impacts of ground-water and air pollution began to demand even greater regulation of disposal practices. In many areas of the nation both open burning of solid waste at dumps and ocean disposal remained an acceptable practice well into the 1970s.

The inability of local governments to deal with these larger problems quickly led to a federal interest and assumption of responsibilities. The first federal solid waste manage-



**FIGURE 1.1** Horse-drawn garbage collection carts at the turn of the century.



**FIGURE 1.2** Horsepower replaces horses in this 1915 version of high-technology garbage pickup truck.

ment law was the Solid Waste Disposal Act (SWDA) of 1965, which authorized research and provided state grants. Three years later in 1968 President Johnson commissioned the National Survey of Community Solid Waste Practices. It provided the first comprehensive data on solid waste on a national basis. Two years later the Solid Waste Disposal Act was amended by the Resource Recovery Act, and the federal government was required to issue waste disposal guidelines.

The year 1970 also saw passage of the Clean Air Act, which established federal authority to combat smog and air pollution leading to the shutdown of many solid waste incinerators and the elimination of open burning of solid waste. Significantly the first Earth Day was celebrated that same year on April 22, 1970, indicating a worldwide heightened environmental awareness including that of the solid waste disposal dilemma. Within a year Oregon became the first state to pass a bottle bill, thereby creating a procedure for government regulation covering the reuse and recycling of designated portions of the waste stream during peacetime without the imperative of wartime economics. Although all 50 states had some kind of solid waste regulation by the mid-1970s, it was the Resource Conservation and Recovery Act of 1976 (RCRA) that created the first truly significant role for the federal government in solid waste management. The act emphasized conservation of resources, particularly energy conservation, and recycling as preferred solid waste management alternatives. It also provided for the national hazardous waste management program, recognizing the detrimental effect of hazardous waste on solid waste management alternatives as well as the environment in general.

The stimulus of the Arab oil embargo, the Public Utilities Regulatory Policies Act of 1978, which guarantees markets for small energy producers, and RCRA combined to encourage an explosive growth for waste-to-energy plants and to some extent the recovery of methane for fuel from landfills. The banning of open dumping of solid waste by the EPA in 1979 increased the attractiveness of waste-to-energy plants because of their volume reduction capabilities. In addition, waste-to-energy plants are generally perceived to be a form of recycling solid waste, as its use as a fuel to create energy does return a significant part of the waste stream to a useful product. This view was, and still is, enhanced by the continuing demand for electrical energy derived from nonfossil fuel sources. However, others, including the State of Florida, do not consider the burning of and recovery of energy from solid waste as recycling. Even today the debate continues with positions taken on both sides as to whether or not waste to energy is legitimately considered recycling.

Although previously preferred to landfills, waste-to-energy plants have now become almost as unpopular with communities unwilling to exchange potential groundwater pollution for potential air pollution. The disposal crisis created by the ever-diminishing lack of acceptable disposal capacity is exemplified by EPA's estimate that over 10,000 landfills (70 percent of the total) closed between 1978 and 1988.

All of those considerations have led to both a public and a legislated demand for recycling as the preferred solid waste management strategy today and in the future. The willingness of government to require and subsidize recycling when necessary has grown to enormous proportions. Significantly the dominant theme of Earth Day 1990 was recycling.

## **Defining Recycling**

Recycling remains, however, one of those elusive concepts about which everyone thinks they have a clear understanding until they begin to practice it. Although most people understand the relatively simple tasks required by individuals in order for them to participate, the subtleties necessary for the interplay of both the public and private sectors need-

ed to return those materials to industry as raw materials and the methods employed to do so require definitions other than common language and as a matter of law. In addition, the concept gives rise to other terms required to fully implement the concept. The terms recyclable materials, recovered materials, and recycled materials all are needed to define the concept of recycling and usually require definition in various state regulations. Therefore, only a dictionary definition of recycling can convey a general concept of a term that has been, and will continue to be, defined through committee discussions, contractual negotiations, and legislation designed to meet specific needs.

## Public Perceptions

Although rapidly changing in response to local public awareness campaigns, the general public's perception of what recycling is remains largely limited to those visible elements including curbside programs, recycling centers, and so on, and a vague understanding that this is good for the environment because these materials do not go to a landfill or incinerator. This view also usually incorporates a demand for recycling a greater variety of materials than is practical or economically feasible at this time or a misunderstanding about what can or cannot be recycled.

Legislative definitions at this time in the evolution of legislation promoting and requiring recycling generally center on those materials in the waste stream that are selectively easy to separate and for which known and relatively stable markets exist. In addition, these definitions ignore previously established industrial recycling efforts based on purely economic needs of avoided cost of disposal and intrinsic value of industrial raw material-derived waste. This kind of legislative definition is directed at promoting additional recycling activities rather than accounting for existing economic considerations.

Current legislation focuses on providing for the promotion of recycling those materials that have not been recycled because the economic reasons to do so do not exist or at least are not readily apparent to the private sector of the economy.



FIGURE 1.3

## **THE WHY'S OF RECYCLING**

---

Recycling occurs for three basic reasons: altruistic reasons, economic imperatives, and legal considerations. In the first instance, protecting the environment and conserving resources have become self-evident as being in everyone's general interest. Second, the avoided cost of environmentally acceptable disposal of waste has risen to a level where when combined with the other costs associated with recycling, it now makes economic sense to recycle many materials. Finally, in responding to both public demand and a growing lack of alternative waste disposal methods, government is requiring recycling and providing for a wide variety of economic and civil penalties and incentives in order to encourage recycling.

## **GROWTH**

---

The support for recycling on both a state and federal basis continues to be explosive and generally responsive to widespread public support and demand. This is a demand that has in many instances outstripped both the public and private sectors of the economy's ability to meet the requirements and/or intent of legislation. In the rush to require recycling, the market for those materials has often been ignored or misunderstood. The entry of the public sector into a traditional and well-established private sector activity has created severe stresses and difficulties in the commodities marketplace for recycled materials. The commodities market is commerce and industry's source of raw materials. It is a traditionally volatile element of the economy that is very sensitive to the relationship between supply and demand for materials. The sudden growth in legislation promoting recycling created an external stimulus that increased the supply of newspaper in the northeastern United States to the point where a glut occurred. In 1989 the price fell not only to zero but was further depressed when communities that were prevented from landfilling recovered newspaper began paying to have it taken away. The phenomenon of negative prices for this commodity severely impacted public programs that were dependent in the past on revenues from this material and those portions of the private sector that were engaged in the recycling of these materials.

However, these kinds of lessons have been helpful and will contribute to better planned and thereby more effective programs in the future. Governments at all levels appear to be directing more and more of their legislation to ensuring markets by creating demand for recycled products through preferential procurement practices. In addition the concept of tax incentives to encourage both recycling and the use of products containing recycled materials continues to gain favor.

## **PROGRAM OPTIONS**

---

Whether anyone wants to recycle for altruistic reasons or because "the law makes us do it," a wide variety of options for recycling are available. Although each option is discussed in detail in other chapters, a central issue that must be considered is that no single option yet available provides all the answers. It is most likely that there is no single option that is best for everyone. There is, however, a best option or combination of options for everyone when a careful evaluation is made to determine what is available to meet specific needs and circumstances.

Recycling debate has evolved into several broad configurations for which examples can be rapidly found in operation today. Innovation, creativity, and practicality provide many variations.

Both residential and commercial establishments can participate in recycling by separating materials before they are mixed with wastes. In these programs recyclable materials are kept separate in a variety of containers whether in the home or in the workplace. At appropriate intervals, they are placed for collection or transported to centralized collection and/or processing facilities.

### **Curbside Collection**

Single-family residential units are often served by curbside programs. These programs may require residents to use one or more containers to separate and store recyclable materials that are diverted from the normal waste stream. The type and number of containers can vary depending on the variety of materials collected and the degree of separation desired. The design, capacity, and construction of the containers can also vary. Some programs provide containers and others do not. Containers may be rigid, specialized plastics, paper or plastic bags; materials can even be bundled or contained at the participant's discretion.

### **Commercial Collection**

Similar programs are also used for multidwelling residential units and commercial applications. However, of necessity these programs do not include curbside collection. These programs require recyclable materials to be placed in specialized containers of the type traditionally used in those applications. Therefore, if a multidwelling unit residence is normally served as a single-family unit for waste, then it can be served as a single family for recycling service. Similarly, if it is served as a commercial establishment for waste collection, then it will probably require recycling service in a similar manner.

### **Commingled or Source-Separated?**

In both residential and commercial applications, the degree of separation may vary significantly. A great deal of commingling can be allowed or required in all instances if a centralized processing facility where commingled materials can be separated after collection is used. Even if a centralized processing facility is not available, single-family residential units can always be allowed to commingle materials by using a truckside sort collection method (Fig. 1.4). This method requires the collector to manually separate the material in the containers and keep them separate in the collection vehicles until delivered to markets or intermediate processing facilities.

### **Material Recovery Facilities**

The use of material recovery facilities (MRFs) serving commingled residential programs is rapidly gaining popularity (Fig. 1.5). Commingled programs used in a multidwelling unit or commercial application can allow efficient collection methods where space available for placement of collection containers is limited.





**FIGURE 1.4** Specialized curbside recycling materials: collection truck with compartments, dual sides, and hydraulic top loading.



**FIGURE 1.5** Materials recovery facility (MFR) infeed conveyors for commingled materials at Community Recycling, an Attwoods Company in Dade County, Florida, that serves over 265,000 homes.