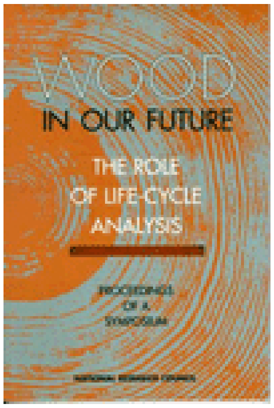

Wood in Our Future: The Role of Life-Cycle Analysis: Proceedings of a Symposium

Board on Agriculture, National Research Council

ISBN: 0-309-52093-2, 144 pages, 6 x 9, (1997)

WOOD IN OUR FUTURE

PROCEEDINGS OF A SYMPOSIUM

Environmental Implications of Wood as a Raw Material for Industrial Use

BOARD ON AGRICULTURE

NATIONAL RESEARCH COUNCIL

NATIONAL ACADEMY PRESS
Washington, D.C. 1997

NATIONAL ACADEMY PRESS · 2101 Constitution Avenue, NW · Washington, DC 20418

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This report has been reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

This study was supported by the Forest Service of the U.S. Department of Agriculture, under Cooperative Agreement No. FP-94-2341. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the view of the organizations or agencies that provided support for this project.

A limited number of copies is available from:

Board on Agriculture
National Research Council
2101 Constitution Avenue, N.W.
Washington, D.C. 20418

Additional copies are available for sale from:

National Academy Press
Box 285
2101 Constitution Avenue, N.W.
Washington, DC 20055
800-624-6242
202-334-3313
http://www.nap.edu

Library of Congress Catalog Card Number 97-66726

International Standard Book Number 0-309-05745-0

Printed in the United States of America

STEERING COMMITTEE ON ENVIRONMENTAL IMPLICATIONS OF WOOD AS A RAW MATERIAL FOR INDUSTRIAL USE

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Preface

At the request of the U.S. Department of Agriculture's Forest Service, the Board on Agriculture convened a symposium on "Environmental Implications of Wood as a Raw Material for Industrial Use" in March 1996 to explore issues related to the use of life-cycle analysis methodologies. Ten symposium papers are included in this report and they address several major topics:

- critical analysis of strengths and weaknesses of life-cycle methodologies;
- emerging issues related to life-cycle assessments of environmental impacts of wood used as a raw material;
- global perspectives, including methodologies used in other countries; and
- potential impacts of methodologies on public policy and international standardization.

The ten papers in this report, as well as the round table rapporteur's perspectives, reflect the authors' viewpoints and do not represent general overall opinions or findings of the symposium steering committee and symposium participants.

Eric Ellwood
John Antle
Gregory Eyring
Peter Schulze
Symposium Steering Committee

The National Academy of Sciences is a private, nonprofit, self-perpetuating society of distinguished scholars engaged in scientific and engineering research, dedicated to the furtherance of science and technology and to their use for the general welfare. Upon the authority of the charter granted to it by the Congress in 1863, the Academy has a mandate that requires it to advise the federal government on scientific and technical matters. Dr. Bruce M. Alberts is president of the National Academy of Sciences.

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The National Research Council was organized by the National Academy of Sciences in 1916 to associate the broad community of science and technology with the Academy's purposes of furthering knowledge and advising the federal government. Functioning in accordance with general policies determined by the Academy, the Council has become the principal operating agency of both the National Academy of Sciences and the National Academy of Engineering in providing services to the government, the public, and the scientific and engineering communities. The Council is administered jointly by both Academies and the Institute of Medicine. Dr. Bruce M. Alberts and Dr. William A. Wulf are chairman and interim vice-chairman, respectively, of the National Research Council.

Contents

APPENDIXES

TABLES AND FIGURES

Tables

Figures

THE STEERING COMMITTEE ACKNOWLEDGES *the outstanding contributions of all symposium speakers and participants representing academia, industry, environmental organizations, professional societies, and other associations throughout North America and Europe. Special thanks is extended to Frank Beall and Joseph Fiksel for their service and coordination of the symposium program.*

WOOD
IN OUR FUTURE

Overview

ERIC ELLWOOD
Symposium Steering Committee

Wood is a widely used raw material. Societal value of wood in the United States and throughout the world is affected by a range of complex issues. The availability and cost of wood, used for so many applications—from housing, to furniture, to reading materials—has come under increasing attention as a result of environmentally driven social and government policies. To some extent, this has led to the use of substitute materials.

At issue is not so much the product of wood and its engineered forms, but rather the concept of preserving natural physical and biologic ecosystems through withdrawal of land from timber harvesting or application of other limiting conditions on timber extraction. These external system values include the structure of a range of ecosystems, with particular emphasis on tropical forests; biologic diversity; habitat for fauna and flora; air and water quality; soil stability; and climate impacts that can be local, regional, or global.

Forest land also should provide scenic, aesthetic, and recreational opportunities for people. The preservation of desirable biologic and physical attributes of forests and provision of scenic, aesthetic, and recreational opportunities must be compatible with timber harvesting—an issue that is being confronted in forest management policy and regulation development.

Another important aspect of the use of wood, as for any material, is energy demand and the nature and type of nonbenign emissions generated during manufacture, use, and disposal. The issue of substitutions for wood as a raw material has been studied with respect to energy, but it has not been addressed regarding the environment. In 1976, the National Academy of Sciences established a Committee on Renewable Resources for Industrial Materials (CORRIM) to study wood as a raw material. This committee's work put primary emphasis on energy consumption in manufacturing and on the potential of wood as a feedstock for chemical energy production. Because emphasis of raw material use has shifted from energy to environmental concerns during the past 20 years, a new scientific assessment is needed to examine environmental assessment methodologies, focus on environmental impacts of wood and wood fiber products, and assess substitution impacts.

To begin to examine the environmental impact of wood use, new methodologies must be applied. Most recently, new methods of analysis (including life-cycle analysis) have been developed to analyze inputs and outputs as they relate to environmental impacts of production of a given item or commodity. The International Organization for Standardization (ISO) is developing standards based on life-cycle analysis methodology for wood-based and other products. The significance of life-cycle analysis is underlined by the 1993 Executive Order by President Bill Clinton requiring life-cycle analysis for federal procurement of environmentally preferred products. Congress approved legislation in 1994 requiring the Department of Defense to undertake life-cycle analysis for major weapons acquisitions.

The U.S. Department of Agriculture's Forest Service requested that the National Research Council's Board on Agriculture address these converging factors, which led to a symposium with the objective of reviewing the state of the art for assessment of the environmental impacts of wood as a raw material. The symposium focused on the science base of methodologies currently in use, reviewed the information needed to judge the adequacy of decision making processes, and explored potential uses of these methodologies.

A two-day symposium with invited speakers was held in Irvine, California, March 14–15, 1996, to examine existing methodologies for identifying and assessing environmental impacts of industrial activities and wood as a raw material choice. The speakers came from private industrial concerns; universities; public interest groups; environmental organizations; and federal, state, and local government agencies.

The first session of the three on the program presented speakers who discussed North American and European efforts in life-cycle analysis and the impacts of international standards development. Identification of deficiencies in methodology and the challenges of application pointed to the need for innovation in accounting methodology and allowed an assessment of the data requirements of alternative approaches. These discussions are presented in Chapters 1–5.

The second session (Chapters 6–9) focused on societal considerations. Industrial marketplace decision making and consumer acceptance of certified products, as well as environmental concerns of production, were discussed.

In the final session, a paper presented by William Hyde (Chapter 10) was followed by a round table discussion (Chapter 11) that focused on policy impacts of life-cycle analysis methodologies and wood as a raw material.

In addition to the three symposium sessions, participants worked in small groups to identify weaknesses and data gaps in current methodologies, generate ideas regarding the enhancement of current life-cycle methodology, and identify appropriate methodology applications (Chapter 11).

Appendix 1 to this volume offers an excerpt from the ISO life-cycle analysis document. Appendix 2 lists participants and the program from the symposium.

LIFE-CYCLE ANALYSIS APPLICATION

At the outset, the symposium brought together a diverse group from the differing backgrounds of forestry professions and other professionals and representatives from industry, government, nonprofit organizations, retailing, consulting, and life-cycle analysis practitioners. This gathering resulted in a spectrum of perspectives. Because life-cycle assessment is a developing field, not all participants came with a detailed understanding of this methodology, and practitioners were, in general, focused on the manufacturing aspects of production. The symposium opened dialogue for better understanding of the methodology and its use.

Life-cycle analysis is a relatively new approach to environmental impact assessment methodology. Although it is clearly a powerful tool, it has limitations. In the simplest terms, it is designed to measure all inputs and outputs in wood production and use from the "cradle to the grave," including mass and energy flows and transformations from origin to and including the final disposal of an item. The degree of precision and the strength of analysis depend heavily on the availability and accuracy of data, the degree of inclusiveness, and the boundaries of the system.

Discussions and presentations during the symposium reveal that the methodology progressively loses accuracy with the complexity of the system, and it is weakest when dealing with nonnumerical data and subjective valuations. Therefore, although the methodology is a significant step forward, there is much to be done to apply other systems in conjunction with life-cycle analysis when dealing with biologic systems and the affiliated study of uncertainties.

Within the forest resources arena, life-cycle analysis is being used primarily by the pulp and paper segment of the forest products industry. To date, it has been a valuable tool for industry—particularly for identifying processes in the manufacturing stream that offer opportunities to reduce impacts on the environment and to increase the efficiency of manufacturing in trade-offs. It also can aid marketing (efforts that use) certificates based on life-cycle analysis. However, the upstream boundaries do not generally include the forest, although the carbon cycle is being investigated. Life-cycle thinking, even if not in detailed analysis, has and is having a beneficial effect on procurement, manufacturing, recycling, and disposal. Two long-term objectives are to identify sufficient standards data and to apply sound science to make comparisons between different raw materials as to their environmental impact.

LIMITATIONS APPLIED TO FOREST RESOURCES

Although life-cycle analyses and life-cycle inventories do provide a powerful way to help assess environmental implications of the use of wood, other approaches are needed. The primary limitations of applicability identified during the symposium involved the lack of adequate descriptive data on the forest resource–forest ecosystem segment of the life cycle and the considerable variability of these forest ecosystems. There also are difficulties in dealing with values that are not amenable to conversion to a number. It is hard to ascribe a specific value to maintaining biologic diversity and habitat to the extent of species endangerment. The diversity of forest ecosystems and differing local and regional conditions make it unlikely that one universally applicable, holistic model will be feasible. The impact assessment phase of life-cycle analysis (which defines the magnitude and probability of the effects of human actions on resources and the environment) involves dealing with unknowns and uncertainties and, therefore, with risk analyses. To a large extent, economic and social impacts must be treated by other means—preferably those that account for input from various groups of people. Depending on the boundaries established and the degree of sophistication they use, life-cycle analyses can be complicated. Notwithstanding the imperfections of the methodology, it is being applied in several industries and is gaining ground as a preferred method for examining the environmental implications of many products. This frequently has led to a "first time" view of a company's vulnerability and opportunities driven by environmental issues. Some government agencies have been directed to use the system as an aid in procuring materials with the least harmful environmental impacts.

Even with its current limitations (it is undergoing rapid evolution in its development), life-cycle analysis does emerge as the most powerful methodology to evaluate the environmental consequences of wood use and most of all to strengthen the science base underlying the system—albeit with caution and with additional systems needed.

MARKETING, CERTIFICATION STANDARDS, AND TRADE

Consumer preferences for environmentally friendly products and systems, given that performance and price criteria are met, create an incentive for industry to use life-cycle analysis in marketing and in educating consumers. This leads to environmental labeling and certification and raises the questions of validity, comparability, and the need for standards, and it introduces the question of whether there should be review of certification by a third party. One experienced practitioner says, the reality behind widely held green issues is often more complex than expected. Hence, the need for sound scientific bases for labeling will prevent the omission of some aspects that could markedly change the apparent overall environmental friendliness of the product or system.

Environmental labeling of consumer products is becoming more common every day. The approach taken by one building materials supplier "to get ahead of the curve" in ecolabeling and in product certification through application of life-cycle inventories is probably a forerunner of an overall trend in retail. Although it is too early to assess the extent to which this trend will take hold, it will result in incentives for manufacturers to reduce environmental impacts in manufacturing.

Programs also are being used in the forest management phase of wood production, for example those of the Forest Stewardship Council and Scientific Certification Systems, Inc. These essentially voluntary programs certify forestry practices that meet their criteria for good management. The criteria focus on sustainability and ecosystem management, and they build a foundation for certification and the chain-of-custody concept. Certainly, certified products tie in directly to the green building approach.

It is too soon to evaluate the effect on the marketplace of the various forest management certification programs, but some reports indicate a premium can be obtained for wood from certified programs. It is apparent that forest certification is having some effect on improving forest management.

Although these certification and labeling programs are positive, industry representatives caution that the programs should be voluntary, that they should involve all stakeholders, and that they should be based on sound science. An important point to consider is that consumers cannot ascertain the "quality" of a product in the market place simply by examining the product; there is a need for information about the process used to manufacture the product and about the consequences of its disposal after consumption. Producing high quality products, or products that are less detrimental to the environment than others, may be more costly to the firms producing them. Consequently, firms must receive a higher price and consumers must be willing to pay more to make production of high quality products economically feasible. Without a mechanism, such as certification or "green" labeling, to assure the consumer that a particular product is worth more, there will not be demand for these types of products. Rather than mandating that firms produce such products, government could collaborate with industry to establish science-based standards and a corresponding certification system that is supported by firms that want to supply certified or "green" labeled products. The cost of certification, then would be born by those consumers who want to purchase certified products.

"Green" labeling of products is gaining ground, particularly in Europe. The European Union is developing a series of ecolabels for numerous products based on life-cycle thinking and has recently issued ecolabel criteria for several paper products. Some countries also have begun to develop management standards for specific forest ecosystems. These programs eventually will influence international trade, raising concerns about specific criteria, the soundness of scientific data, and the impartiality of the programs. A major concern for future international trade that was not addressed in the Uruguay Round of the General Agreement on Tariffs and Trade (GATT) negotiations or any other multilateral trade agreements is the use of nontariff trade barriers to inhibit trade. Existing international trade agreements allow countries to prevent importation of products that do not meet science-based standards for health, safety, or environmental impact. The key issue is defining a "science-based" standard. In this context, the issue of science-based standards for life-cycle analysis and "green" labeling is important, especially in light of the recognized limitations of current life-cycle methodologies and their application. While life-cycle analysis is clearly a valuable tool and holds much promise for the future, it is a rapidly progressing new methodology and currently cannot be considered a comprehensive science-based procedure for national or international standards and certification.

The ISO is active in developing voluntary standards in environmental management tools and systems. ISO 9000 deals with production-oriented issues, and ISO 14000 is concerned with management issues, including life-cycle analysis. Forest management is not specifically included but there are plans to do so. The purpose of the standards—involving a multistakeholder approach—is to establish criteria for planning, implementation, and review rather than to define actual performance standards. The United States, taking a proactive role, is involved with the ISO standards development primarily through representatives from industry and professional organizations.

Most of the development of standards has been from voluntary stakeholder participation, but government agencies have an interest in standards and certification and in their underlying methodologies. The U.S. Environmental Protection Agency is interested, and policy makers are looking to the methodologies as aids for decision making. It was suggested during the symposium's roundtable discussion, that, in the United States, the preferred role of government could be to support the development of sound science-based methodologies, encourage the involvement of stakeholder groups, and foster market-driven approaches rather than to take mandatory regulatory action.

FOR THE FUTURE

Symposium participants agree that a clear understanding should be sought about the environmental consequences of forest management and the associated uses of wood because of their national importance. The symposium itself has encouraged forward thinking about ways to promote multidisciplinary activity in this subject. The controversies, strengths, and weaknesses of life-cycle analysis were brought out at the meeting. Issues surrounding the use of wood, ecolabeling, certification, consumer acceptance, and international trade and standards were discussed.

Further exploration of the ideas generated at this symposium could lead to consensus among stakeholders, could enlarge and enhance public understanding of the issues involved regarding environmental impacts, and should provide a sounder scientific basis for public policy development.

Symposium participants suggested ways to advance and enhance the use of current life-cycle methodology. It was generally recognized that an objective, scientifically based analysis is needed that builds on our knowledge of raw materials energy impacts outlined in the 1970s and that now turns the focus to environmental impacts. This environmentally focused analysis could identify a framework for use of methodologies; compare impacts of different raw materials on the basis of and within the limitations of these methodologies; and suggest coordination between government, industry, environmental organizations, consultants, and nongovernment organizations regarding the use of impact assessment. The objectives would be to examine the science base for life-cycle methodologies; identify data that are lacking in current methodologies; suggest research needs; examine the value and impact of wood production in comparison with other raw materials; outline appropriate coordination efforts among stakeholders; and suggest appropriate mechanisms for valuation of environmental, economic, and social aspects of raw materials use.

PROCEEDINGS

CHAPTER 1

Life-Cycle Thinking for Wood and Paper Products

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Scott Paper Company

Life-cycle analysis examines the physical behavior of industrial systems. The fate of raw materials is traced from their extraction from the earth to their final disposal. All materials, including packaging materials, must be accounted for. Therefore, even when paper and board products do not form the central materials flow, it is impossible to analyze systems in which paper, board, and wood products are not involved. It is therefore important to have a logical and consistent method for life-cycle analysis for these products; this chapter discusses factors to consider.

When the idea of life-cycle analysis was developed in the early 1970s, it emphasized the use of energy and raw materials in inorganic systems; and the analyses gave little, if any, mention of emissions to air or water. The starting boundary for such systems was defined as the point at which materials are taken from the earth (through mining or oil and gas extraction, for example), and because minerals, oil, and gas are inert, their ultimate disposal to a landfill meant that any effects after landfilling could be ignored.

When paper and board products were incorporated into life-cycle analyses of industrial systems, their treatment was essentially ad hoc. The starting boundary usually was placed at the felling of the timber, and, as with inorganic systems, the finishing boundary was placed at the point at which the paper was placed in a landfill. There was relatively little energy recovery from the incineration of paper, so this, too, posed few perceived problems. By treating wood products in this way, the carbon source did not enter into the analysis, and the fate of the carbon after disposal was similarly excluded from the system.

The handling of wood feedstock (the energy content of the wood) was, however, more cavalier. Wood and wood products clearly contain bound-in energy.

They can be burned and the energy reclaimed. Some analysts included it in the same way as they did the feedstock energy associated with synthetic polymers. Others omitted it. Several arguments were advanced for omitting this component of energy, but most owed more to value judgments and interpretation than to science. They ranged from the simple sentiment that "omitting makes the numbers lower," through the more sophisticated "the energy is free and should not be included," to the pseudoeconomic "wood is not a commercial fuel and so should not be treated as though it were one."

The problem with omitting wood feedstock from calculations is that it leads to the absurd conclusion that some processing steps are net producers of energy. For example, if paper in municipal waste is incinerated and energy is recovered, then the incinerator is a net producer of energy from an energy-free feed.

Today, however, life-cycle analyses are done with an increasing degree of sophistication, and many of the systems involve not only wood but other biologic products. Furthermore, the system boundaries are being pushed back to the initial planting of the tree as a seedling (in some cases even nursery operations are included, although some seedlings occur naturally) through to the effect of any products after they have been landfilled. It is therefore essential to take a consistent approach to analyzing all biologic systems and to account for all the potential burdens that could influence the impact of their products.

WOOD AND PAPER

Wood is a complex structure consisting of four main components: cellulose, hemi-cellulose, lignin, and extractives. The relative proportions of these components vary from one species to another, but Table 1-1 shows typical percentages.

Cellulose is a carbohydrate polymer with an empirical formula $(C_6H_{10}O_5)_x$. Note that hydrogen and oxygen are present in the same proportions as in water—hence cellulose is a carbohydrate. Hemi-cellulose is a polymer mixture of carbohydrates, principally glucose, mannose, and galactose (isomers of $C_6H_{12}0_6$) and xylose and arabinose (isomers of $C_5H_{10}O_5$). Lignin is an extremely complex polymer structure with repeat units typically having the empirical formula $C_{178}H_{200}O_{70}$. The extractives are low-molecular-weight compounds, principally

TABLE 1-1 Typical composition of wood

Component	Weight %
Cellulose	45
Hemi-cellulose	25–35
Lignin	21–25
Extractives	2–8

terpenes, phenols, fatty acids, and, in softwoods, resin acids; they are called extractives because they can be readily extracted with neutral solvents.

For paper making, the best fibers are those that consist of cellulose with substantial quantities of hemi-cellulose, but with all of the lignin and extractives removed. Paper and board substrates can therefore be regarded as carbohydrates that contain 45 percent carbon by weight.

THE CARBON CYCLE

A tree absorbs atmospheric CO_2, water, and sunlight for conversion to the materials we call wood and bark. After felling, the wood is treated to liberate cellulose fibers and remove lignin and extractives. In the course of this process, most of the waste products—and increasingly, the bark—are burned to generate some or all of the steam needed in the process. The fibers are then converted to paper, which, in an integrated process will again use some of the energy derived from waste wood products. The result of burning the paper products is that some of the CO_2 that was fixed when the tree was growing is liberated to the atmosphere. After use, the consumer can either burn the paper, liberating more of the fixed CO_2, or send the waste for disposal with other rubbish. At final disposal, the waste could be incinerated, liberating the remaining fixed CO_2. It could be sent to a landfill, where it decomposes aerobically, to liberate CO_2, or anaerobically, to liberate hydrocarbons, which, after decomposition in the atmosphere are converted to CO_2. The sequence is shown in Figure 1-1.

If trees are continuously replaced as they are felled, all of the carbon in the system is recycled eventually; that is, carbon is a constantly cycling burden. Within the system there is a time mismatch. A tree might take 50–100 years to reach the felling stage. Its conversion into paper can occur within a matter of months from felling, and its use and disposal also could be measured in months. If, after disposal, the waste products are hydrocarbons, the rate of decomposition in the atmosphere is unknown, but it probably is tens if not hundreds of years. If,

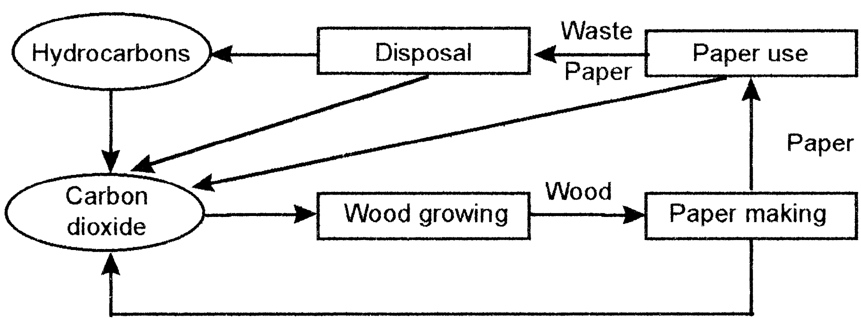

FIGURE 1-1 Materials flows in the wood and paper products system.

however, the system is operated so that the rate of replacement of timber mass by planting and growing at least matches the rate of extraction, then the system would exhibit a carbon equilibrium apart from any hydrocarbon emissions; this is discussed later. This equilibrium system, on a global scale, will be relatively insensitive to the rate of extraction, provided that the rate of extraction is small compared with the total mass of standing timber.

Starting Boundary

Whether the consumption of CO_2 by a tree as it grows should be included in a life-cycle analysis depends on where the starting boundary is drawn. If it is placed at the point of felling the tree, then the absorption of CO_2 would be omitted. If however, the boundary is placed at the point at which the tree is planted, then CO_2 absorption must be included. In a true life-cycle, the starting point would most obviously be placed at the point of planting, in which case the inputs to the system will be CO_2, water, and any other nutrients; the wood is simply an internal flow within the system boundary.

To be consistent, if the emission of CO_2 during the processing of wood products is recorded, the corresponding input of CO_2 to the system must be considered at the growing stage. Otherwise, the simple carbon balance will be violated; that is, the system would be acting as a generator of carbon atoms.

ENERGY BALANCE

Only a small fraction of the sun's energy falling on a tree is absorbed and used. Nevertheless, what is absorbed is used to fix the carbon, which manifests itself as the energy content of the wood. This feedstock energy depends on the type of tree and whether the wood is oven dried or air dried. Typical ranges are shown in Table 1-2.

Feedstock energy must be included in energy calculations. It is, however, important to keep its contribution to the overall total energy separate from other contributions—in the same way that electrical energy is kept separate from the contribution of fossil fuels. It is also important to recognize that, within the

TABLE 1-2 Typical ranges for wood calorific values

Wood type	Drying method	Calorific value (MJ/kg)
Softwood	Air dried	14–18
	Oven dried	17–23
Hardwood	Air dried	13–14
	Oven dried	17–19

paper-processing sequence, some of the feedstock will be converted to fuel—as when waste products of pulping are used to generate steam.

The inclusion of wood feedstock energy as a separate contribution to the overall energy total is particularly important when examining integrated pulp and paper plants and when judging the efficacy of paper-recycling processes. By including wood feedstock in calculations for integrated pulp and paper plants, total energy might not be reduced compared with nonintegrated plants; indeed, it might actually be increased because of the lower conversion efficiencies of wood-fueled boilers. The critical factor is not total energy but the amount of fossil fuel energy that is put into the system. When judged in terms of fossil fuel input, integrated plants usually show significant benefits because fossil fuels are displaced by wood products.

In paper-recycling processes, the option to use waste wood products does not occur on any significant scale. There is occasionally some burning of sludges to generate steam, but the calorific value of such sludges is low. All the energy input to the system must be fossil fuel based. Thus, even if the total energy for the production of recycled paper is less than that for the production of virgin paper, the increased use of fossil fuels in recycling processes usually means that virgin production should be favored because of its lower use of fossil fuels.

Much of the controversy over whether wood feedstock should be included in calculations centers on the total energy of the system. Energy should not be reported as a single value; the contributions of different fuels and feedstocks are far more important than is the total. When judging the efficiency of a process it is the quality of the energy used rather than the amount of energy used that is important. Renewable wood energy is preferable to nonrenewable fossil fuel energy.

PAPER IN LANDFILL

The precise fate of paper deposited in a landfill is not fixed. Depending on the nature of the landfill, the paper could decompose entirely in a relatively short time or it could remain intact for a long period. This depends on such factors as temperature, acidity, the presence of bacteria and nutrients, the composition of the waste, and the form of the paper—shredded paper would decompose faster than would an intact telephone book.

The basic decomposition reaction for cellulose is well known:

$$C_6H_{10}O_5 + H_2O = 3CH_4 + 3CO_2 \quad (1)$$

Only half of the carbon present in paper will result in methane formation during decomposition. Typically, carbon constitutes 45 percent of the mass of paper. Thus, the carbon content of 1 kg of paper will be 0.45 kg, and that giving rise to methane, assuming 100 percent decomposition, will be 0.225 kg. The mass of methane produced will be 0.30 kg and the corresponding mass of the coproduct CO_2 will be 0.83 kg. This will not necessarily be emitted to air; if a landfill emits significant quantities of methane, the gas usually would be collected for use as fuel.

Interest in this form of decomposition arises because of the potential greater global warming effects of methane compared with CO_2. We can gain some insight about this effect by using a global warming potential of 11 for methane (based an a 100-year time horizon). With 100 percent decomposition, as in Equation 1 above, the CO_2 equivalent of the gases emitted is 4.11. If all of the carbon is emitted as CO_2—as would occur with incineration—the CO_2 equivalent is 1.66; that is, about half of the decomposition value. Clearly, incineration is preferable to decomposition, and given the potential for energy recovery at incineration, there is a strong case to be made for burning paper products.

SUMMARY

When dealing with wood products in life-cycle inventories, there are six points to apprehend:

- Carbon dioxide absorption during tree growing should be included in the analysis.
- Carbon dioxide emissions from wood product incineration must be included in the analysis.
- The feedstock energy of wood inputs must be included in calculations.
- When wood feedstock is used as a fuel in intermediate processes, the change must be calculated.
- Energy must be reported in sufficient detail so that the contribution of wood fuel and feedstocks can be identified; reporting energy as a single number is meaningless.
- Quantification of methane emissions from landfilled paper is still imprecise, but if it is included, at the least, the yield, measured in terms of CO_2 equivalents, will be increased by a factor of 2.5 compared with the CO_2 emitted during complete incineration.

The primary aim of life-cycle inventories and life-cycle analyses is to provide the data needed to inform decision making. They are complementary to economic, social, and political considerations but do not replace them. When used improperly, they are useless—as are all decision-making tools. But when used properly and intelligently, they provide insights about the working of industrial systems that are unavailable elsewhere.

CHAPTER 2

Committee on Renewable Resources for Industrial Materials: A Look Back and Consideration of the Future

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Land use decisions that encourage substituting other materials for wood are made daily at all levels of government in the United States. Although generally motivated by a desire to protect the environment, such decisions, and the deliberations that lead to them, rarely account for the effects of substitution triggered by land use constraints. This is a critically important omission, and one that is leading to environmental decisions and regulations that are adverse, rather than beneficial, to the global environment.

A decision to eliminate or sharply reduce harvests on a given land area obviously reduces the environmental impacts associated with timber harvest and subsequent regeneration. However, in the absence of planning to reduce overall consumption of raw materials, and the goods made from them, that decision also automatically triggers global market mechanisms to replace or substitute raw materials for those that have been made unavailable. Research, including that of a mid-1970s National Research Council (NRC) Committee on Renewable Resources for Industrial Materials (CORRIM), has shown that the environmental impacts associated with raw-materials substitution are substantial—in many cases greater than the environmental damage that restrictions on forest harvesting seek to avoid (National Research Council, 1976a,b).

It is no surprise that raw-materials-related environmental decision making in the United States can lead to environmentally damaging policies. The NRC's CORRIM research is the only comprehensive study of environmental effects of renewable raw-materials production and use done in the United States—and that study is now 20 years old. Consequently, there is today an almost total lack of current information about the environmental impacts of raw-materials extraction, reduction, processing, and use.

A renewed attention to U.S. industrial raw-materials policy is strongly suggested. In particular, it would be useful to promote systematic life-cycle analyses of renewable materials, with a focus on the environmental effects of renewable raw-materials production and use.

CORRIM II: THE NEED IS GREAT

Policy and management decisions by federal, state, and local agencies have begun to affect the ability of domestic forests to meet even the local demand for wood raw materials. Recent actions have led to sharp reductions in forest harvesting on federal lands, and the pressure is mounting to reduce harvesting on private lands. Such actions and pressures are based almost completely on environmental concerns. However, because decisions that influence the management and periodic harvesting of forests are not linked to U.S. consumption, the effect is simply to transfer demand to regions outside our borders or to trigger substitution of nonwood materials.

The mid-1970s NRC CORRIM study (1976a) quantified the energy use associated with production and use of wood and other building materials. Based on its results and the findings from several more recent studies outside the United States (Arima, 1993; Buchanan, 1991; Meil, 1994; National Commission on Materials Policy, 1973; National Research Council, 1976a; Richter and Sell, 1992), it is clear that materials substitution results generally in large increases in energy consumption (and all associated environmental impacts) for raw-materials gathering and processing. The net effect is that the environmental impacts of both materials substitution and the increased demand for wood from foreign sources are likely to cause significant harm to the global environment.

Because wood accounts for a large portion of the nation's industrial raw-materials consumption, significant restrictions on domestic wood production will tend to trigger the amount of substitution and import activity on a massive scale. Thus, environmental, economic, and other effects will not be trivial. It is, therefore, extremely important that economic, strategic, and global environmental concerns be considered as part of each proposal for domestic environmentally based action. In this context, current data are needed to reflect current technologies and life-cycle considerations for various material options.

Even though the investigation of the environmental consequences of substitution was part of the mandate of the original CORRIM effort, it was impossible then to examine any consequences other than energy impacts. It has subsequently become clear, however, that the sort of effort that CORRIM devoted to the energy consequences of renewable resource use could be used to study other environmental impacts as well. Today, some of these non-energy-related environmental impacts are more important, or at least of more immediate social interest, than are the energy-related environmental impacts.

The energy conservation opportunities of materials substitution vary over time as processing technologies change and as product designs are modified. These changes call for updating the findings of two decades ago. It is unrealistic to expect that the NRC study's findings are as useful today; the data need to be updated periodically. Furthermore, as noted before, the nonenergy consequences of substitution have not been studied systematically or quantitatively.

Today, decisions are being made in the name of environmental quality that significantly affect the capacity to sustainably produce wood and wood fiber in U.S. forests; these decisions are being made in the absence of sound scientific data concerning the environmental impacts of wood use. As noted in the NRC CORRIM report:

> The U.S. has unique opportunities to increase the use of renewable resources as industrial materials. These resources derive from the growth of living organisms, plants and animals, using a large and very productive land base. Within U.S. borders are included some of the most productive lands in the world for the production of biologically based resources. The nation has selected to emphasize the use of much of this highly productive land base for the effective production of food. It has not had the same national commitment to the production of renewable materials.

This statement has more relevance today than it did when it was written. The United States continues to make policy decisions that increase its almost 80 years of dependence on foreign imports of wood. Moreover, the same advocacy groups that press their position on the United States are advising its potential suppliers to reduce their production of wood as well. All of this is based on a weak, indeed almost nonexistent, scientific knowledge base concerning the environmental consequences of using wood as a material of commerce.

HISTORICAL PERSPECTIVE

The United States developed and prospered in its early history largely through the use of its rich endowment of natural resources, the first of which to be exploited was the forest. Wood was the predominant fuel used in early America. Forests supplied materials for the construction of homes and other structures. Wood was, in fact, among the first exported commodities, and its sale permitted colonists to buy manufactured products from Europe. Many of the ships that brought colonists from England returned loaded with ships' timbers obtained from the forests of New England. With the discovery of coal, oil, and a variety of mineral deposits, these natural resources added to the mix of materials that contributed to the development of a new nation. With the growth of a transportation infrastructure, primarily through the construction of the railroad network that was augmented by water transport via canals, rivers, lakes, and coastal waters, whole communities developed around the exploitation of forests and mines.

As the easily accessed natural resources of the populated Northeast were exhausted, this area of the country was supplied from the less developed lands in the South, the Midwest, and ultimately the far West. But with the local reduction in the supply of natural resources in the Northeast came a concern in some segments of society for the supply of essential materials. In the forestry sector this concern often focused on fear of a "timber famine." For example, Gifford Pinchot, the father of American forestry and a consummate politician, pressed on his political mentor Theodore Roosevelt the necessity of adding dramatically to forest reserves with the prediction that "at the present rate of use the country will run out of timber in twenty years." Looking back, it is clear that fears of a timber shortage were unfounded and partly the result of a lack of recognition of forest renewability.

The use of materials of all kinds, including wood, has continued to increase even though individual products have become obsolete or disappeared entirely from use. The pattern of materials use has changed dramatically over the years, but demand for materials of all kinds has increased. As materials have become more costly they have been used more efficiently.

The forest famine syndrome that was a significant part of early American forestry had its counterpart in other materials sectors. From time to time this concern for materials supply resulted in the appointment of various committees and commissions to study the subject. Sometimes groups focused on a material or group of materials; sometimes they examined a broader spectrum. After World War II and the Korean War there was public concern about the shortage of materials for military use in wartime. This led President Harry S. Truman to appoint the Paley Commission to study materials supply from the vantage point of national security.

National Commission on Materials Policy

In the late 1960s, the beginnings of concerns related to the relationships between materials supply and the environment surfaced and resulted in the passage of the National Materials Policy Act of 1970 which included a mandate to the president to appoint the National Commission on Materials Policy. The commission's charge included determination of

- national and international materials requirements priorities and objectives, both current and future, including economic projections;
- the relationship of materials policy to national and international population size and to the enhancement of environmental quality;
- means for the extraction, development, and use of materials that can be recycled or reused or that self-destruct, to enhance environmental quality and conserve materials;

- means for exploiting existing scientific knowledge in the supply, use, recovery, and disposal of materials and for encouraging further research and education;
- means for enhancing coordination and cooperation among federal departments and agencies in materials use to best serve the national materials policy;
- the feasibility and desirability of establishing computer inventories of national and international materials requirements, supplies, and alternatives; and
- assignment of continuing responsibility for the implementation of the national materials policy to specific federal agencies.

The commission made its report to the president and Congress in June 1973 (National Commission on Materials Policy, 1973). The completion of its studies very nearly coincided with the start of a major petroleum shortage in the United States and with the initiation of many studies of energy supply. The information supplied by the commission was an important part of the relevant data base for the studies that came after.

CORRIM

After a review of the work of the National Commission on Materials Policy, the Science and Technology Policy Office (STPO), in support of the science adviser to the president, determined that the various studies of materials supply, while recognizing that wood was important, did not focus on it sufficiently. Recognizing this deficiency, the STPO requested that the National Academy of Sciences (NAS) "reexamine the role of renewable resources, as the other major component of natural resources, in helping better to meet the needs for materials in the future." In response, NAS appointed the NRC's CORRIM, whose mandate included the following:

- Quantitative analysis of current materials flows for renewable resources as the basis for assessing the impact of potential future changes (compared with nonrenewable flows). Definition of the limitations (cost and technical) of renewable resources for meeting expanding demands for materials based on them. Delineation of the energy, environmental, and social consequences of such increases, as well as their international aspects.
- Assessment (stocktaking) of the interchangeability of renewable and nonrenewable resources as the basis for materials.
- Assessment of the quantity and quality of research and development in the area of renewable resources by the federal government and industry.
- Evaluation of the relationship of these activities to the size of the industry and its role in the economy. Assessment of changes in scale and emphasis needed to meet future changes.
- Evaluation of relevant federal, state, and local legislation and regulations that influence the effectiveness of the development and use of renewable resources.

- Improvement in materials properties and performance.
- Improvement in the yield of raw materials and in the efficiency of processing.
- Determination of the potential of renewable resources as feedstock for synthetic materials—cellulose based and converted products (such as ethylene)—that can be used to supplement or replace the petrochemical supply used for synthetic polymer production.
- Consideration of the energy requirements and environmental impacts associated with the implementation of the recommendations.

Some 80 scientists representing industrial, government, and university research organizations spent more than 2 years studying the issues raised in the mandate from STPO. The NRC's CORRIM submitted its final report in 1976. Because of time and budget limitations, and because of the critical energy supply problems that were the focus of national attention at the time, most of the efforts of CORRIM were dedicated to the energy consequences of substitution of renewable for nonrenewable resources. The NRC study revealed numerous opportunities to make significant energy savings through such substitution (National Research Council, 1976a,b).

INDUSTRIAL RAW MATERIALS TODAY

The United States today is a net importer of the raw materials used by its economy. An examination of Table 2-1 shows that the proportion of imports is substantial for numerous materials, including most metals, cements, petrochemicals, and wood and wood products.

Consumption in the United States of many materials per unit of gross national product is falling and per capita consumption of many materials is level or nearly so (exceptions in the U.S. are plastics, paper [Williams, 1991], and wood and wood products in general; per capita consumption of these materials has risen significantly in the past several decades). Demand for industrial materials in developing nations, however, is rising steadily. Increases in population and purchasing power within developing regions will likely accelerate the demand for raw materials globally; industrial output and energy use are expected to triple worldwide and to increase fivefold in developing countries (World Bank, 1992).

Within this context, and given the desire within the United States to maintain a strong economy and balance of payments, it is prudent to consider whether the country is adequately positioned for the future with respect to industrial raw materials. Will industrial raw materials be available at reasonable costs through the next century? If so, what are the implications for the U.S. balance of trade in the years to come? Might the availability of materials obstruct the goal of affordable housing nationally? What effect is increasing U.S. demand for industrial raw materials from foreign sources likely to have on the global environment? How

TABLE 2-1 Net U.S. imports of selected materials as a percentage of apparent consumption, and by major foreign sources[a,b,c]

Material	% Imported	Principal Foreign Sources (1991–1994)
Columbium	100	Brazil, Canada, Germany, Thailand
Mica	100	India, Brazil, Finland, China
Manganese	100	South Africa, Gabon, France, Brazil
Graphite	100	Mexico, Canada, China, Madagascar, Brazil
Strontium (celestite)	100	Mexico, Germany
Bauxite/alumnia	99	Australia, Jamaica, Guinea, Brazil
Fluorspar	92	China, South Africa, Mexico
Platinum group	88	S. Africa, United Kingdom, Belgium, Germany
Tungsten	87	China, Germany, Bolivia, Peru
Tin	84	Brazil, Bolivia, Indonesia, China
Cobalt	82	Zambia, Norway, Canada, Zaire
Tantalum	80	Germany, Australia, Canada, Brazil
Chromium	78	South Africa, Turkey, Zimbabwe, Russia
Potash	74	Canada, Belarus, Germany, Israel
Titanium	—	Russia, Japan, China
Silver	—	Mexico, Canada, Peru, Chile
Barium (barite)	65	China, India, Morocco
Nickel	61	Canada, Norway, Australia, Dom. Republic
Antimony	60	China, Mexico, South Africa, Hong Kong
Petroleum (crude and refined)	53	Saudi Arabia, Venezuela, Canada
Magnesium compounds	50	China, Canada, Mexico, Greece
Asbestos	46	Canada
Zinc	41	Canada, Mexico, Peru, Spain
Silicon	33	Brazil, Canada, Russia
Gypsum	30	Canada, Mexico, Spain
Aluminum	25	Canada, Russia, Venezuela, Brazil
Cadmium	21	Canada, Mexico, Belgium, Germany
Iron and steel	21	EEC, Canada, Japan, Brazil, South Korea
Iron ore	18	Canada, Brazil, Venezuela, Australia, Mauritania
Sulfur	18	Canada, Mexico
Portland and masonary cement	17	Canada, Spain, Greece, Venezuela, Mexico
Wood and wood products (total)	12	Canada, New Zealand, Chile
Copper	3	Canada, Chile, Peru

[a]Also significant import dependency for andalusite, arsenic, bismuth, caesium, copper, diamond (industrial), gallium, gemstones, germanium, ilmenite, indium, iodine, iron and steel slag, kyanite, lead, leather, lime, mercury, mica, natural rubber, nitrogen, pumice, pyrophyllite, quartz, rhenium, rubidium, rutile, salt, selenium, sodium sulfate, stone (dimensional), tellurium, thallium, thorium, vanadium, vermiculite, wool, yttrium, zirconium.

[b]U.S. Department of the Interior. 1996. Mineral Commodity Summaries. Geological Survey and Bureau of Mines.

[c]Data for wood, wood products, and wood pulp products are from U.S. Forest Service, Forest Products Laboratory.

might such demand affect efforts by developing nations to create adequate shelter for their expanding populations? These are but a few of the questions that should be addressed.

Renewable materials, particularly wood, today occupy a position of great importance in the U.S. industrial raw materials picture. It is interesting to note that, on a weight basis, wood use in the United States roughly equals the combined use of all metals, all plastics, and all cement consumed each year.

CORRIM II: A VISION

As a result of a series of meetings held in Vancouver, British Columbia, in November 1991, organized by Frank Beall, president of the Society of Wood Science and Technology, an effort to update and expand the NRC's CORRIM report was begun, based on the recognition that a better understanding is needed of how the global environment is affected by the production and use of various industrial materials.

A steering committee was independently selected after the Vancouver meeting to pursue funding for a project assuming the name CORRIM II. This group adopted a mission statement, and it took steps to create a multiuniversity research organization to conduct and coordinate the work of scientists from across the nation.

The scope and mission statement adopted by the independently formed CORRIM II Steering Committee is as follows:

1. Conduct a quantitative analysis of material and associated energy flows and balances for a wide range of construction components and systems and packaging materials using renewable and potential substitute resources including recycled materials; incorporate life cycle or "cradle to grave" considerations. Focus on evaluation of wood and agriculturally-based materials, and include in the analysis comparisons with impacts associated with producing and using steel, aluminum, plastics, concrete, and emerging composites.

2. Examine the interchangeability of renewable resources and potential substitutes as the basis for materials. Survey new and emerging advanced composite materials to determine substitutability for more traditional materials.

3. Assess the historical improvement in the yield of raw materials, efficiency of processing, recycling, and in materials properties and performance, and examine current and emerging technologies that will likely influence these issues in the future.

4. Evaluate the environmental impacts and long-term sustainability issues associated with the use of each resource studied, including assessment from both domestic and global perspectives. Evaluations would include examination of international trade linkages and environmental implications of materials substitution, including transportation effects.

5. Identify legislation and regulations that influence the development and

use of domestic renewable and non-renewable resources. Evaluate the environmental, economic, and other implications of public policy with respect to raw materials from both domestic and global perspectives.

Members of the CORRIM II Steering Committee are listed at the end of this chapter.

Summary

The need for industrial raw materials in the United States and elsewhere is virtually never considered in the development of U.S. environmental policy. It is an extremely serious omission that bodes ill for both the global environment and the U.S. economy. Moreover, although it is critical that materials needs be addressed, there is today little information available on which to base decisions. Specifically, current scientifically based information about the relative environmental impacts of gathering, processing, using, maintaining, discarding, or reusing materials—in particular, wood and other organic materials—does not currently exist.

A comprehensive study of environmental impacts of materials use, with a focus on wood and wood fiber products, is proposed.

CORRIM II STEERING COMMITTEE[1,2]

Jim Bowyer, *Director, Forest Products Management Development Institute, Department of Forest Products, University of Minnesota (Chair)*
Don Berry, *Manager, Timber Resources, Trus Joist MacMillan, Boise, Idaho*
James Bethel, *Dean Emeritus, College of Forest Resources, University of Washington*
Conor Boyd, *Vice President, Weyerhaeuser Company, Tacoma, Washington*
J. Carrette, *Director, Wood Products Division, Forestry Canada*
Raymond Cole, *School of Architecture, University of British Columbia*
Ed Diekman, *President, GFDS Engineers*
Irving Goldstein, *Department of Wood & Paper Science, North Carolina State University*
Douglas Greenwood, *American Institute of Architects, Washington, D.C.*
Susan LeVan, *Assistant Director, U.S. Forest Products Laboratory, Madison, Wisconsin*
Bruce Lippke, *Director, CINTRAFOR, University of Washington*
Con Schallau, *Chief Economist, National Forest Products Association, Washington, D.C.*

[1] Several committee members have subsequently left the committee due to retirement or change in employment.
[2] CORRIM II is an independently-formed steering committee and is not a committee of the National Research Council.

Roger Sedjo, *Senior Fellow, Resources for the Future, Washington, D.C.*
Jim Shaw, *President, Canadian Wood Council*
Ron Slinn, *Vice President, American Paper Institute*
Warren Thompson, *Dean, School of Forest Resources, Mississippi State University*
Ross Whaley, *President, State University of New York College of Environmental Science and Forestry*
Peter Wrist, *President & Chief Executive Officer, Pulp and Paper Research Institute of Canada*

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CHAPTER
3

Assessing Environmental Impacts of Wood Used as a Raw Material in North America

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This chapter discusses features of the methodologies used to assess the environmental impacts of using wood as a raw material in North America. The reader is assumed to be familiar with the general concepts of the life-cycle analysis and the inventory, impact, and interpretation—improvement stages identified by the Society of Environmental Toxicology and Chemistry (SETAC) in describing life-cycle assessment (LCA). Strictly speaking, such assessments cover the cradle to grave scenario: extraction of resources; manufacture of intermediates, ancillaries and main product; transportation, packaging, and distribution; use, recycling, and disposal. (Portions of the full scenario can be taken, but only if the reasons for doing so, the scope of the study and the boundary conditions are carefully described and justified.) Finally, it is assumed that inventory procedures are well defined compared with those for impact.

To discuss impact methodologies it is necessary to understand something of the life cycles and possible impacts, and even general philosophies of approach, that can be involved.

EXTRACTION

Although wood is called a "raw material" it should be recognized that, in LCA language this term applies to resources taken from the earth. In this sense, therefore, wood is not a raw material, but an intermediate material obtained from trees extracted from the forest. The soil, minerals, air, and water of the forest provide the basic raw materials and the environment for growing trees, and it follows that the boundary for LCA studies involving wood must include the forest operations.

The extraction of trees from forests immediately raises several impact questions:

- Are the forests temperate or tropical?
- What tree varieties are present? Which are to be harvested? What are their ages, growth rates?
- What geology, terrain, and soil types are involved?
- What fertilizers or herbicides are used?
- What is the condition of the rivers and streams?
- What flora, fauna, and fish species have been identified? What is their condition?
- What will be the effects on atmosphere and climate?
- What ownership, social, or political effects are expected?
- Is the forest well managed (now and in the future)?

These questions are complex and often interdependent. The public is concerned about several of them, probably because of news stories about the endangerment of animal species, the loss of rain forests to burning, and the loss of jobs.

Most life-cycle studies to date have ignored many of the issues posed in the questions above. To be fair, the studies mainly have been inventories, concerned primarily with mass and energy data, which have discussed impacts using the "less is better" paradigm for the data at hand.

Neglect also can be ascribed to the scarcity of data, the formidable complexity of the forest ecosystem, and the fact that forests need to be studied on at least a regional basis. Before tackling impact effects associated with the extraction of trees from forests, it appears that serious work should be undertaken to inventory the above factors. For example, some reports state that in some rain forests there are literally thousands of yet unidentified species.

Several organizations have engaged some of these tasks, and a few organizations, upon careful study and if proven, will provide certification for good forest management. To a LCA practitioner of life-cycle analysis, such studies must appear worthwhile because, if carried to absolute standards, the data would be acceptable and would relieve the practitioner—and his/her audience—of many concerns. It should be noted that, although there is some discussion about the subject, forest management is not currently part of International Organization for Standardization (ISO) 14000. Also, ISO 14000 does not set absolute performance standards.

The Canadian Standards Association has initiated some work in this arena—including studies aimed at selecting inexpensive and effective methods for obtaining impact data.

FIREWOOD AND ENERGY

Firewood, the simplest wood product, raises important issues. Trees grow through photosynthesis—converting CO_2 from the atmosphere and water to wood (small quantities of other compounds are also involved). When the tree is burned, heat (as converted energy from the sun) is obtained and combustion CO_2 is released back to the atmosphere. Crudely:

• If the tree (and its ancestors) has been around a long time and it is not replaced, the burning of the tree increases the concentration of CO_2 in the atmosphere. (There is a parallel here to the burning of fossil fuel where hydrocarbons are taken out of the earth and combustion CO_2 ends up in the atmosphere.)

• If, however, the tree grows again or a new tree is planted (and it is nurtured), the combustion CO_2 is reabsorbed to make new wood. (Here, it is relevant to note that compared with burning fuel oil the burning of wood is cleaner; it produces fewer oxides of sulfur and less ash, for example.)

Thus:

♦ Trees convert primary compounds to wood—a valuable raw or intermediate material.

♦ Combustion of wood (or derivatives) provides energy obtained from the sun.

♦ A carbon cycle is involved, which is important because it includes atmospheric CO_2—a major contributor to global warming.

♦ Wood is a renewable resource.

♦ In a broad sense, the growing of trees and the use of wood can tend toward a “sustainable” operation.

All of this influences impact.

LUMBER

Figure 3-1 illustrates the flow of materials and products associated with lumber. The extraction of the tree from the forest, transportation, and other products or activities (such as use of bark, sawdust, and fuels or preservatives) are not identified in this drawing.

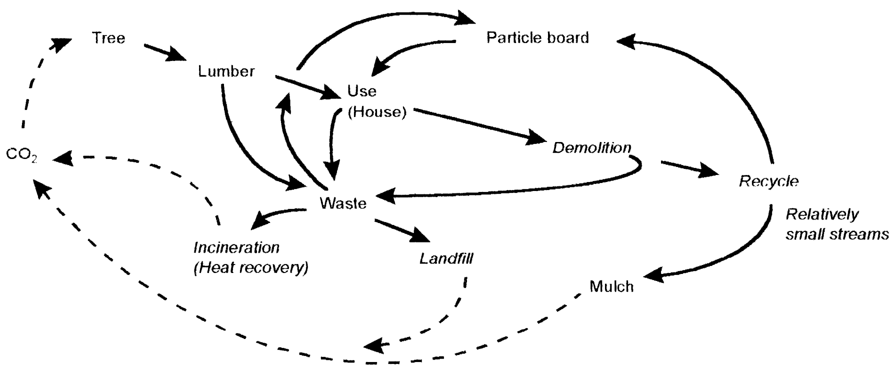

FIGURE 3-1 Flow of materials and products associated with lumber.

Factors that influence impact as shown in the diagram include:

- Recycle loops, in which wood is shown to be recycled into particle board and mulch. These operations, particularly particle board manufacturing, eliminate the use of new wood, and because they do not seem to require much in the way of energy or other resources, can be considered generally beneficial in reducing impact.
- Lumber, which after use can be incinerated for energy recovery.
- The carbon cycle, which is more complex than that for firewood. Here, in addition to burning, some wood, in the form of mulch or once it is placed in landfills, decomposes to generate CO_2 (at least partly as methane, a worse global warming culprit than CO_2). Transportation and processing, of course, add more fossil-fuel-derived CO_2 to the scenario.

Degradation of wood (and paper) in landfills is intriguing. The biologic–bacterial action responsible for degradation, which may be thought of as low-temperature reaction or combustion, apparently depends on the presence of moisture. A really dry landfill could be used as a carbon sink. It could provide a route for taking CO_2 out of the atmosphere and storing its carbon equivalent in the ground. The obstacle is the need for dryness.

OTHER PRODUCTS

A chart similar to Figure 3-1 could be drawn for various paper products. Other exciting possibilities for using wood (biomass) as a raw material are being studied. These include the use of renewable wood as a raw material to generate heat and electrical energy in power stations, to manufacture chemicals, or to produce alternative nonfossil fuels for automobiles, for example. These developments will affect not only the carbon cycle but, among other things, will also affect SO_x emissions, land use, and social systems.

GENERAL APPROACH TO IMPACT EVALUATION

Impact evaluation can range greatly in detail—with five different levels of complexity being recognized. The simplest method applies a "less is better" approach to inventory data virtually collapsing the inventory, impact, and improvement steps into one. The method is crude and lacks discrimination. For example, it is unable to decide whether less SO_x is better than less CO_2—to say nothing of more complicated issues. Nevertheless, the method provides a low-cost baseline and is effective in simple cases and in highlighting possible problem areas.

Studies then rise in complexity to highly detailed, often expensive, ones that seek to provide impact determinations for the specific sites involved. This is similar to an extended risk assessment task. For a life-cycle project this becomes impractical because it implies that multiple risk assessment studies should be made across the whole life-cycle scenario. Current impact methods are at about the third level of complexity.

It could be argued that one of the hopes for life-cycle analysis was to obtain a single number to rank impact-related desirability. (As an aside, some Swedish practitioners have described many impacts in monetary units.) The LCA techniques now in use aggregate many factors over a whole life cycle. Perhaps the desire for a single unit stems partly from the fact that it is easy to handle mass and energy quantities—the only items used in early studies (mainly inventory studies). Whatever, the general approach to impact evaluation has proceeded to narrow down the number of parameters toward the ultimate single target.

The host of impact items to be evaluated is large and might be described as an impact phase space. This incorporates the operations involved (possibly a large number of processes at different locations and, as an example, we will consider four processes identified as A through D), the impactors involved (possibly many chemicals and gaseous emissions, such as CO_2, SO_x, and various other wastes), and impact effects or categories (global warming, acid rain, and human carcinogens). In approaching this problem, most current impact studies proceed from impact categories and chains through classification, characterization, and valuation stages.

Impact Categories and Chains

Impacts can have chain effects extending to secondary and higher order, though not necessarily greater, impacts of different kinds. Moreover, several compounds initiate the same primary impact (acid rain is triggered by SO_x, NO_x, or HCl). The impact chain that stems from acid rain as an impact category is shown in Table 3-1.

Impact Matrix

Given several impact categories, a matrix can be constructed for a project to show which impacts could be expected after accounting for impact chains. As a hypothetical partial example, consider processes A through D shown in Table 3-2.

TABLE 3-1 Impact categories and chains

Stressor	Primary	Secondary	Tertiary	Quaternary
SO_x	Acid rain	Building deterioration	Resources	
		Water quality	Aquatic biota	Reduced diversity and fishing
		Vegetation effects	Agricultural production	
		Soil effects	Vegetation effects	

TABLE 3-2 Sample impact matrix

	Process or operation[a]			
Impact category	A	B	C	D
Acid rain		x	x	x
Global warming	x	x	x	x
Resource depletion	x	x	x	x
Plant toxicity	x			x
Decreased water quality		x	x	
Human carcinogens		x		
Solid waste	x	x	x	

[a]Each "x" in this table indicates a process that generates the impact. Several impactors could contribute to this impact.

Classification

Classification groups together all compounds contributing to a given type of impact. As mentioned, SO_x, NO_x, and HCl can contribute to acid rain. Each "x" in Table 3-2 for acid rain may therefore represent the amount of SO_x, NO_x, and HCl taken from the inventory for a given process. Likewise, several compounds, including CO_2 and CH_4, contribute to global warming.

Characterization

The hazard potential of each compound (or activity) in an impact group is now normalized by applying a multiplier (called an equivalence factor) that expresses the potential for harm relative to a chosen baseline. For global warming, as an example, CO_2 provides the baseline. Referencing processes B through D, extracted from Table 3-2, for example, we obtain the results shown in Table 3-3.

The application of equivalence factors allows each impact category in matrices like that shown in Table 3-2 for operations A through D to be described in

TABLE 3-3 Hazard potential

	Operation		
Item	B	C	D
Gas	CO_2	CO_2	CH_4
Weight	w	y	z
Equivalence factor	1	1	11[a]
Total stressor in CO_2 units = [w + y + 11*z]			

[a]The equivalence factor for CH_4 takes both initial potential and persistence into account.

terms of total relative units. This total could be called "total characterized stressor value."

Several groups are working to measure or estimate equivalence factors for various materials and impacts. Basic acidification factors have been developed; methods are available for human carcinogenicity (by using IARC designations); and factors for ozone depletion are well known. In some cases the translation of relative hazard potential to absolute impact is difficult to define—but these questions are receiving attention.

Location

It can be observed from the above that the impacts most easily handled are those that involve gases with global effects. This stems from the free release of gas into the atmosphere. The situation is different when liquid or solid wastes are involved; these are released locally and do not have vast and open dispersion opportunities. This is a feature of the methodology in which aggregation begets aggravation. Thus, there is something lacking in lumping all wastewater quantities together, or all quantities of a suspect chemical emission, across a life cycle because releases are made in different areas having different topographies and sensitivities. Also, no dose rates—usually required for the more local risk assessment work—are immediately known.

Some things can be done to ameliorate this situation, however, and more will be forthcoming. For example, in handling acid rain it has been shown that, by studying maps showing areas that have sensitive soils and by identifying regions with large acid gas emissions, it is possible to develop weighting factors (similar to the equivalence factors discussed above) to express regional differences across the continental United States (see Figure 3-2). The use of such factors can be viewed as a modifying tool and a partial return to risk assessment locales.

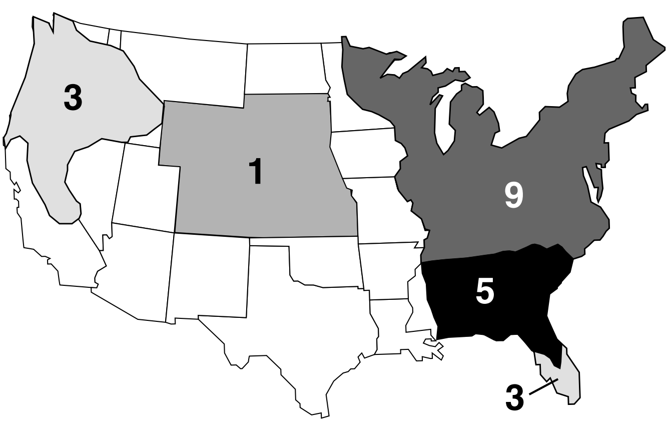

FIGURE 3-2 Equivalence factors for acid gas emissions impacts in the continental United States.

At this point it should be said that it is inappropriate to expect life-cycle analysis to handle local problems with risk assessment detail. To attempt to do so would prove prohibitive. The objective would be to develop impact evaluation to identify possible problems within and between systems and then, turning inward, to highlight where the ("local") problems might be—problems that can then be studied more carefully, as necessary. It should be pointed out that life-cycle analysis practitioners have more than just aggregated numbers at their disposal. Some details for specific operations (such as processes A or D in the foregoing discussion, for example) are already available for study.

Valuation

Once final total characterized stressor values are calculated, it is necessary to determine their relative significance. This is a judgmental exercise that can be undertaken by experts to rank the importance of the impact effects. This is aided by an analytical hierarchical process after another normalizing step is taken. The structure that could apply is shown in Table 3-4, along with a few hypothetical weighting values to illustrate a breakdown that might be obtained.

The generation of weightings is essentially a subjective exercise—carried out in a structured manner aimed at providing consensus values. Different groups of experts—environmentalists, scientists, engineers, government officials, local politicians, citizens—have different agendas and will likely generate different

TABLE 3-4 Hypothetical valuation structure

Total impact (1.0)	Global (0.4)	Ozone (0.05)	
		Warming (0.08)	
		Resources (0.07)	
	Regional (0.3)	Acid rain	
		Smog	
		Water use	
		Particulate	
	Local (0.3)	Human health	Inhalation
			Carcinogens
		Land use	Waste disposal
			Resource extraction
		Envir. health	Terrestrial toxicity
			Aquatic toxicity
			Eutrophication

valuation factors. Overall, however, when a given set of such weighting factors is applied to the normalized total characterized values for the various impact categories, a single numerical figure is obtained that represents the method's assessment of the life-cycle's impact, including the experts' valuation.

Several computer programs are under development to incorporate various aspects of these methodologies.

SUMMARY

- Life-cycle impact assessment is still in relative infancy. It is a complicated, challenging, and changing arena.
- Forests can be inventoried, planned, and managed intelligently—with the goal of doing so to absolute performance standards. This is a demanding, long-term task.
- Depending on definition, a large degree of sustainability can be obtained in using wood as a raw material. Wood is a renewable resource.
- Carbon cycle considerations are important.
- Wood offers opportunities to produce energy, chemicals, and alternative fuels while reducing increases in atmospheric CO_2 concentrations.
- Computational methods for assessing impact currently permit a fair degree of comparison to be made between the impacts of systems.
- The results highlight areas for further examination.
- Work is continuing to improve the general methodology for impact assessment.
- Some aspects of the methods used tend toward risk assessment venues.
- Computer programs are being developed to handle impact calculations.
- No one has all the answers and much remains to be done. Progress, however, is remarkable.

CHAPTER 4

European Assessment Methodologies

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Over the past 10 years, environmental issues have assumed an increasing priority for government and industry alike. In the United States and in Europe, the emphasis of environmental research has gradually shifted from specific sites to specific products or processes. As a result, specific regulations have been enacted that address the environmental impact caused by specific products. One example is Executive Order 12873, signed by President Bill Clinton October 20, 1993, which requires in section 503 that the Environmental Protection Agency (EPA) "issue guidance that recommends principles that executive agencies should use in making determinations about the preference and purchase of environmentally preferable products."

This is one of several reasons why tools are needed to scientifically assess the overall environmental performance of products and their associated industrial systems. In numerous industrial countries, life-cycle assessment and its most developed component, life-cycle inventory analysis, are now recognized as belonging to that category of tools. Life-cycle analysis provides quantitative information about of the environmental impacts of industrial systems. By offering an unbiased analysis of entire industrial systems, life-cycle analysis has shown that the reality behind widely held beliefs regarding "green" issues is more complex than one might expect.

Wood is a material of choice for many industrial and commercial products. More and more life-cycle analyses are performed for wood-based products, and the methodology is rapidly evolving, especially in Europe.

This chapter details recent developments in Europe for both the life-cycle inventory methodology and life-cycle impact assessment methodology.

LIFE-CYCLE ANALYSIS: BASIC PRINCIPLES

Life-cycle analyses are concerned with the impact of extended systems sequences of industrial operations on the environment. In the case of a product, the system encompasses the entire life cycle, from raw-material extraction to the different end-of-life management alternatives (landfilling, incineration, recycling, reuse), including the manufacturing stages, transportation, distribution, use, and waste collection.

A complete analysis involves three main steps, and several tertiary ones:

1. The *inventory* is used to calculate material and energy inputs and outputs from the system. This phase includes:
   - the definition of system boundaries (which steps are included in the system and which are not) regarding the goal and scope of the project;
   - data collection needs for each step previously in the system; and
   - calculation of the final inventory. The detailed inventory results are classified into five main categories: raw material consumption, energy consumption, air emissions, water effluents, and solid waste.
2. The *impact assessment*, in which the flows compiled in the inventory are translated into environmental impacts (natural resources depletion, greenhouse effect, photochemical smog, water toxicity, and so on).
3. The *improvement analysis*, evaluates needs and opportunities for reducing the environmental burden associated with the system studied. This phase is connected to the initial goal and scope of the project.

METHODOLOGY STATUS

Despite the lack of official standards, many harmonization schemes have greatly helped reduce existing differences in life-cycle analysis methodology. The situation is different for each step of the analysis:

- The inventory phase is now well settled and there are almost no differences among the methods used by experienced practitioners. The methodology has been summarized in a U.S. EPA publication, Life-Cycle Assessment: Inventory Guidelines and Principles, and in the proceedings of Society of Environmental Toxicology and Chemistry's (SETAC) workshop, Guidelines for Life-Cycle Assessment: A Code of Practice.
- The impact analysis phase is currently under development, and there is as yet no generally accepted methodology. However, some techniques have been developed and yield practical results, and Ecobalance, my company, has gained experience in using them.
- The improvement analysis phase is related to management consulting practices and relies more on practitioners' industrial experience and their ability to understand and deal with clients' needs, than it does on actually formulating a methodology.
- The International Standardization Organization (ISO) is currently working to standardize the methodology under the ISO 14000 series.

INVENTORY METHODOLOGIES: GENERAL PRINCIPLES FOR SYSTEM BOUNDARIES

The theoretical principle of life-cycle analysis dictates that each material and constituent should be traced back to natural resources (energy and raw materials) taken from the environment or to substances and energy released to the environment (emissions to air, water, and soils). These could be called "elementary flows" (crude oil, iron ore, CO_2 emissions). Each time a nonelementary flow (diesel oil, steel) appears, practice calls at least theoretically for system boundaries to include the production processes leading to this product and its end of life, until all elementary flows induced by its production (and use) are accounted for. Extension of the system allows reduction of nonelementary flows to elementary ones (Figure 4-1).

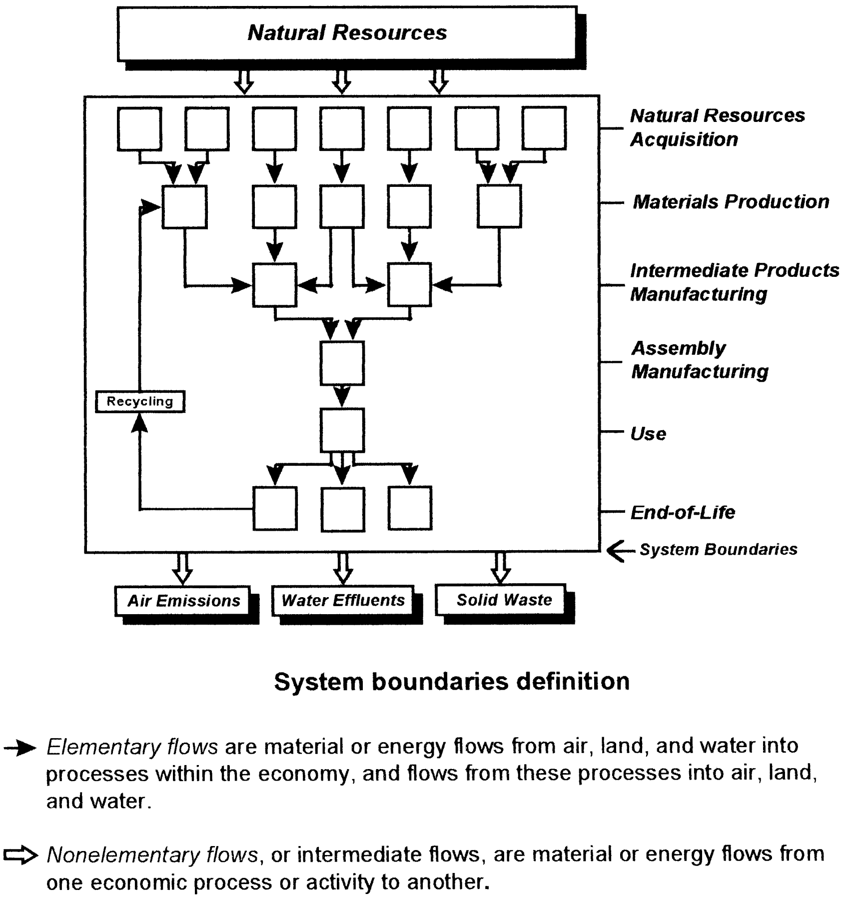

FIGURE 4-1 System boundaries.

Until recently, wood was considered a natural resource; an input to the system. However, more European countries are now considering this assumption false and are leaning toward considering wood as an intermediate flow, inside the system under study. So wood is no longer a raw material; the seed is at the beginning of the cycle. Several studies set to begin in 1996 consider forests as industrial systems.

The European Commission, under pressure from northern European countries, is considering life-cycle analysis studies of oaks, spruces, and beeches. Concurrently, the French Ministry of the Environment is contemplating a life-cycle study of poplars and Oregon pines. The forest can be seen as an *industrial system,* which includes all forestry activities, and as a *natural system,* which is the intersection of the main biogeochemical cycles.

FORESTRY ACTIVITIES AND SYSTEM BOUNDARIES

The reasonable upstream limit of the forest system boundaries is the seed itself, because the inputs and outputs (fuel, fertilizer) required by a tree to produce one seed are negligible. Thus, the forest is a system that uses energy and material input from the environment and generates emissions to the environment in the process of converting seeds to harvested wood.

Inputs and outputs of several steps are taken into account: nursery; site preparation; planting; tree growth, including herbicide and fertilizer application and CO_2 uptake; and harvesting (Figure 4-2).

For each step, data are collected on the consumption of water, fuel, herbicides, and fertilizers. The system boundaries are extended to include the production of the main inputs consumed—fuel and fertilizers—on the basis of their weight.

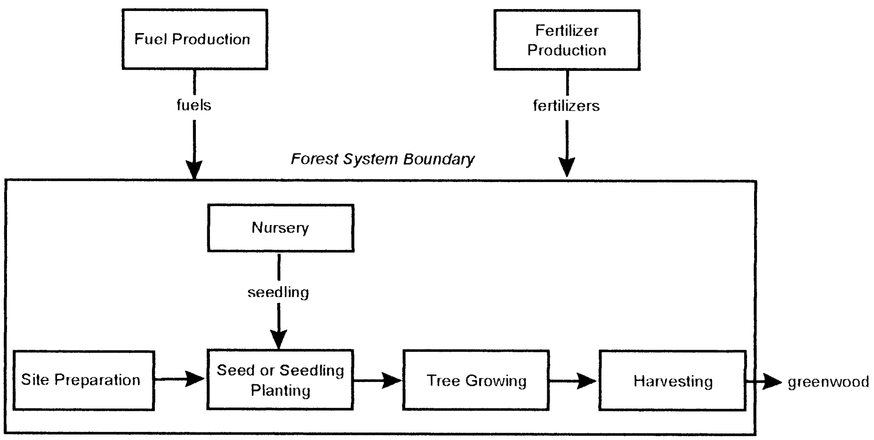

FIGURE 4-2 Steps in the forest system boundary.

Note that, in reality, a significant fraction of the wood used in forest products comes from trees grown from natural regeneration rather than from planted seedlings. Naturally regenerated trees generally carry a lower environmental burden than do planted trees, because they avoid the chemical and energy consumption associated with nursery, site preparation, and fertilization. Therefore, considering a forestry system model in which 100 percent of the harvested wood comes from planted trees ensures that the burdens estimated in the life-cycle inventory for the forestry step are conservative.

FORESTS AS NATURAL SYSTEMS

Forests, like other natural systems, are complex (Figure 4-3) and scientific knowledge about them is limited. There is both uncertainty in the model parameters and natural variability in the real forest systems being modeled as far as the flows of carbon, hydrogen, oxygen, nitrogen, phosphorus, and potassium are concerned.

Nonetheless, the specific nature of wood should be reflected in the life-cycle inventories and taken into account when interpreting these inventories. This is particularly relevant for the treatment of emissions of CO_2 and other greenhouse gases, and for the treatment of the energy, and mass indicators that might be included in the life-cycle inventories. Carbon dioxide uptake and renewability are studied in the following sections.

CO_2 Uptake and Release

The carbon content in wood products is derived from the CO_2 absorbed by trees when they grow (photosynthesis). The carbon atoms are either released at the end of life of the products, in the form of CO_2, CO, hydrocarbons, or methane molecules, when the products are burned or decomposed in landfills, or during

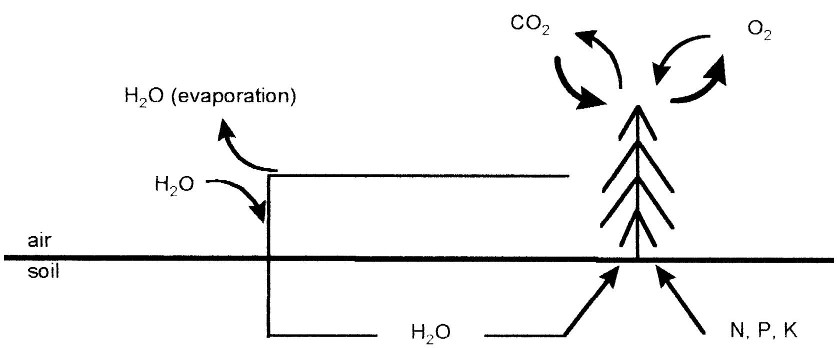

FIGURE 4-3 A tree and its environment: main physical inflows and outflows.

composting, or they can remain trapped in landfills for decades if decomposition is incomplete. From the life-cycle inventory of the releases we must subtract CO_2 uptake or sequestering during forest growth as part of the total carbon cycle.

Renewability

Wood is a renewable resource. Forest net growth, defined as total growth less mortality, in the U.S. (22,525 million cubic feet per year in 1986) currently exceeds forest harvesting (16,450 million cubic feet per year) (Waddell et al., 1989). No change in this proportion is expected for decades to come. This is why consumption of renewable energy resources should be distinguished in life-cycle inventories from consumption of nonrenewable energy resources (such as oil and gas).

This does not mean that harvesting a tree has no impact on the equilibrium of the forest. Restocked species are not necessarily the same as those harvested, and regions harvested are not necessarily the same as those planted. But this observation is more relevant from a biodiversity or sustainability point of view than from a renewability point of view and should be addressed in a subsequent impact assessment stage.

The issue of the renewability of wood is separate from the issue of CO_2 uptake, which should be accounted for regardless of the issue of renewability. Whether a harvested tree is replaced by a replanted tree or not is independent of the fact that the harvested tree has consumed CO_2.

LIFE-CYCLE IMPACT METHODOLOGIES: ECOPOINTS SYSTEM

"Ecopoints" are used to represent the environmental load of a system, based on the inventory of inputs to and outputs from the system (the life-cycle inventory). The lower the score, the better the environmental performance as measured with ecopoints.

The process for calculating ecopoints is as follows:

1. Ecofactors are defined for items typically found in life cycle inventories.
2. Each item in the inventory (for which an ecofactor exists) is then multiplied by its ecofactor.
3. The ecopoints have the same dimension and can be added up to obtain four separate partial scores for air emissions, water releases, energy consumption, and waste outputs.
4. The total score—the total environmental load—is then obtained by adding up the four partial scores.

The Ecopoints method was developed in Switzerland. It is fully explained in Ahbe et al. (1991). An ecofactor for a given item is calculated from an estimate of the total annual emission (or consumption) of the item in the country of reference (annual flow, F) and the maximum acceptable annual emission (or consumption) of the same item for the country of reference (critical flow, F_k). The ecofactor (E) is then given by: $E = (1/F_k)*(F/*F_k)*10^{12}$. The lower the critical flow, the higher the ecofactor. The closer the annual flow is to the critical flow, the higher the ecofactor. A constant (10^{12}) is used for improving the readability of the results.

The ecopoint score (S) for a given item is given by $S = E*X$. X is the amount of the item in the inventory. Because the ecopoints have been developed only in Switzerland so far, the values for F and F_k used in Europe are those given for Switzerland.

CRITICAL-VOLUME SYSTEM

Critical volumes also were devised in Switzerland. The method is presented in *Ecobalance of Packaging Materials* (1990). Critical volumes are used in addition to an energy indicator and a solid-waste total, to build what the authors call an "ecoprofile," based on inventories or ecobalances of the production of materials and on their end of life, as estimated in Switzerland.

Critical volumes are calculated for air emissions and water releases. The critical volume for a given item amounting to X mass units in the inventory is given as critical volume = X/limit value. The limit values are taken as regulatory limits. There are limit emissions values for air, and limit emission values for water (when emissions limits are missing for air releases, then emission limits are used after an appropriate scaling). Swiss regulation is used for most regulatory limits.

Critical volumes corresponding to air emissions for which a regulatory limit coexists are then added up to obtain a total air critical volume.

Critical volumes corresponding to water releases for which a regulatory limit exists also are added up in order to obtain a total water critical volume.

ENVIRONMENTAL PRIORITY STRATEGIES

A detailed description of the environmental priority strategies (EPS) system is found in Steen and Ryding (1992).

The Environmental Priority Strategies system is one of valuation, in which emissions of substances to the environment and extraction of resources from the environment are common measures, that can be compared or added. The mathematical procedure is as follows: each quantity emitted or extracted is multiplied by its corresponding *environmental load index.* The result is an *environmental load value.* The dimension of this quantity is the same for all emissions and extraction; it is called the ELU, or *environmental load unit,* 1 ELU amounts to ECU in OECD countries.

The EPS report consists of long tables with environmental load indexes.

There are 20 raw materials, including fossil gas, oil, aluminum, and copper, for which such an index is defined. There are 14 chemicals that can be emitted to the air or to water and for which such an index is defined. Among them are CO_2, ethene, and SO_2. There are four types of land use that can be assessed. The index is based on a number of so-called *safeguard subjects*:

- biodiversity;
- human health;
- production;
- resources; and
- aesthetic values.

These safeguard subjects are chosen because the Swedish Parliament has decided to protect human health, preserve biologic diversity, maintain a long-term housekeeping of natural resources, and protect the natural and cultural landscape. For each subject, a valuation of the basis of the willingness to pay has been derived. This willingness to pay concerns an average estimated societal value; for example, 106 ECU for excess death. The relation of emissions and extraction with impact types is more scientific, although many uncertainties are present and many assumptions have been made. An example of this is the impact of 1 kg CO_2. There are impacts on health, biodiversity, and production; some impacts are negative, others are positive. The greenhouse effect has several negative effects; one of them is drowning due to a rise in sea level. A positive effect is a decrease in the occurrence of cardiovascular diseases. Eight impacts are considered, and the sum of all partial environmental load indexes yields the net environmental load index for 1 kg CO_2 emitted to the air.

Before all, it should be noted that the EPS is a system under development. Nevertheless, several critical remarks apply here. The first concerns the valuation of different types of safeguard subjects. It turns out that depletion is highly valued compared with human health. The valuation of depletion is derived from the possibility of recovering materials from dump sites, for example. For human health, a completely incomparable method of valuation is used. The result is that a human being is not even worth his weight in silver! Another objection concerns uncertainty with respect to the impacts of emissions. Whereas some people claim the greenhouse effect does not even exist, it is at least awkward to attribute a rise of sea level—and a concomitant increase in death by drowning—to emissions of greenhouse gases. The extrapolation in terms of reduced life expectancy due to both positive and negative contributions is even more problematic.

CML CLASSIFICATION SYSTEM

The Centre of Environmental Science of Leiden University or Centrum Milieukunde Laden (CML) life-cycle assessment method of comparing alternative products on the basis of environmental effects has four steps; goal definition, inventory, classification, and evaluation. A description can be found in Heijungs et al. (1992). In the goal definition phase, the subject of study is demarcated, questions to which the study must give an answer are identified, and a functional unit is defined. In the inventory stage, a table is generated of the intervention in the environment for one functional unit. Apart from complete and detailed process data, assumptions on recycling and allocation must to be integrated in the inventory table. During the classification component, the potential environmental impact of the interventions in the environment is determined. In the evaluation phase, the results of the classification are evaluated.

Selection of Environmental Problem

Table 4-1 gives a standard list of environmental problem types. Other problems might be included if they do not coincide with problems already listed.

Definition of Classification Factors

For each problem, classification factors are defined. For depletion of abiotic resources, the known reserves determine the score. Depletion of biotic resources is measured by a biotic depletion factor (BDF), determined by the reserves and the reserves-to-production ratio. In the CML guide, these two problem types have had little attention. Factors are lacking for all but a very few resources.

The translation from emissions into contributions to pollution problems is worked out in great detail. This translation is acquired by multiplying the emission by a factor determining the substance's contribution to an environmental problem, relative to a reference substance. For the greenhouse effect, emissions

TABLE 4-1 Environmental problem types

Depletion	Pollution	Damage
Depletion of abiotic resources	Enhancement of greenhouse effect	Damage to ecosystems and landscapes
Depletion of biotic resources	Depletion of ozone layer Human toxicity Ecotoxicity Photochemical oxidant forming Acidification Nitrification Waste heat Odor Noise	Victims

Source: Centrum Milieukunde Leiden (CLM). Leiden, The Netherlands.

are translated into CO_2 – CFC-11 equivalents. The calculation of the equivalents per substance are based on general environmental modeling, taking into account the potential effects, environmental behavior, extinction rate, and the environmental compartment to which the substance is emitted.

For damage problems, simpler factors are defined. For ecosystems and landscape damage, area is the factor; for people, it is the number of victims.

Creating the Environmental Profile

The environmental profile is created by presenting the results of the effect scores for all considered alternatives on all selected environmental problems, in tables, graphs, or both. The alternatives can thus be compared by their scores for each environmental problem separately.

Normalization of the Effect Scores

The effect scores from the environmental profile can be "normalized" by comparing them with a reference effect score, for example, to the yearly world total contribution to a given environmental problem. This can help with interpretation of the environmental profile, and in fact it can be viewed as the first step of the evaluation. A "normalized environmental profile" then emerges.

Conclusion

In Europe, a consensus is now emerging to consider tree harvesting as part of the life-cycle system boundaries. This implies a careful inventory, and knowledge of all emissions occurring during tree growth.

On the impact assessment side of the methodology much controversy remains. However, methodologies such as the CML classification system, which makes a clear distinction between the clarification and valuation steps of the impact assessment methodology, seem to gain more and more ground.

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CHAPTER
5

International Organization for Standardization: Environmental Management Systems Standards

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For many reasons, corporations have begun to look closely at integrated environmental management. This scrutiny has been aimed at reducing risk, becoming better corporate citizens, improving their public image, responding to shareholder concerns, and improving the workplace environment. An underlying reason for these goals is to improve a company's environmental performance. In response to this growing interest in environmental performance, the International Organization for Standardization (ISO) confirmed the need for and agreed to prepare an international consensus document for Environmental Management Systems (EMS). In 1992, ISO formed a Technical Committee on Environmental Management (TC 207) with a scope that included the "standardization in the field of environmental management tools and systems" (International Organization for Standardization, 1996. Environmental Management Systems). ISO specifically excluded from this scope test methods and limit values for air, water, soil, and noise pollution; specified environmental performance levels; and the standardization of products.

Since its formation, TC 207 has been working in several areas to produce international consensus agreements to publish as voluntary standards. These include EMSs, environmental auditing, environmental labeling, environmental performance evaluation, and life-cycle assessment. The first document to reach the International Standard stage was ISO 14001, published as "Environmental Management Systems—Specification with Guidance for Use," September 1, 1996, First Edition (International Organization for Standardization, 1996). This chapter reviews the genesis and components of ISO 14001 and discusses the existing options for determining conformity with ISO 14001.

GENESIS

Often referred to as a "paradigm shift," ISO 14001 represents the culmination of thinking regarding the way to manage environmental performance. Although ISO 14001 is a new standard, the concept of environmental management systems has been around for many years. In fact, ISO used preexisting standards, regulations, and charters, including ISO 9000 Quality Management Systems, the British Standard BS 7750 (International Organization for Standardization, 1996), the European Union Eco-Management and Audit Scheme (EMAS) (International Organization for Standardization, 1996), and the International Chamber of Commerce Business Charter for Sustainable Development as a starting point for drafting ISO 14001. Although the principles included in ISO 14001 are not new, it represents a multistakeholder, international consensus opinion on EMS. This consensus approach is intended to engender broad-based international acceptance and use of ISO 14000.

GENERAL COMPONENTS

Divided into five sections, ISO 14001 outlines the process an enterprise considers to manage environmental matters. The key principles include items such as

- a well defined process for planning,
- support and commitment of top management,
- the identification of individuals and procedures to implement plans,
- the communication of those plans, and
- a process of review.

In this way, ISO embraced a "plan–do–review," approach to environmental management.

POLICY

ISO considered the environmental policy as the source from which an organization should derive the particulars of its system. It contemplated this environmental policy as the "driver for implementing and improving the organization's EMS" (ISO 14001, Annex A, Section A.2). To act as such a driver, ISO recognized the vital importance of upper-level management involvement in and commitment to an environmental policy. Thus, ISO 14001, Section 4.2, requires top management to define its environmental policy.

Although mandatory, ISO recognized that policies will necessarily vary from organization to organization. However, minimum requirements for such a policy are mandated by the EMS. They include commitment to continual improvement of the environmental management system, the prevention of pollution, and the compliance with applicable environmental laws and regulations.

PLANNING

As the next step toward an EMS, ISO recognized that all organizations must take stock of environmental matters, set goals for their improvement, and make provisions to achieve the goals. To be applicable to a range of enterprises, ISO did not specify goals. Instead, the planning section of the EMS requires minimum components of a planning process and leaves to the enterprise the specification of details for the EMS.

ISO 14001 Section 4.3 has been distilled by many to read, "Say what you do...." In this planning stage, ISO set forth the following steps: identify environmental aspects and legal and other requirements, set objectives and targets, and establish a formal environmental management program. For the environmental aspects and legal requirements, ISO 14001 requires an organization to "establish and maintain procedures" to identify its environmental aspects and legal and other requirements.

An organization also must establish, maintain, and document its objectives and targets for all relevant levels of the organization. Under an informative guidance on the use of the specification, ISO further states that these objectives and targets must be "measurable wherever practicable" (ISO 14001, Annex A, Section A.3.3). These objectives and targets also are linked directly to the implementation and operation section of ISO 14001.

IMPLEMENTATION AND OPERATION

Colloquially, the language in ISO 14001, Section 4.4 requires an organization to "...do what you say." Certain of those requirements relate to the human aspects of an EMS and include roles and responsibility, education, communication, and training. The remaining requirements focus more on procedural matters of an enterprise. They include document control, operational control, and emergency preparedness and response.

To implement ISO 14001, an organization will necessarily rely on individuals. ISO requires the organization to determine who will implement the various components of its EMS, how it will communicate information to all levels of the organization, and how it will provide the necessary resources and training to do so. Here again, ISO refrains from mandating specific action, recognizing that the "how" will necessarily vary from one organization to another.

The procedural components of ISO 14001.4.4.5 require an organization to have a documentation system that contains the core elements of the EMS and that is readily obtainable. An organization also must examine its operations and activities (normal, abnormal, and emergency) and link that information with the identification of "significant" environmental aspects and the setting of relevant objectives and targets for improvement. Specifically, ISO 14001 requires an organization to understand how its operations affect the environment and to relate those effects to continual improvement of its EMS and the prevention of pollution. In ISO 14001.4.4.6, the threshold for "significance" is left to the organization.

The operational control section of the standard also contains the only reference to suppliers and contractors. Although not clearly articulated, ISO 14001 requires an organization to understand how suppliers and contractors produce "significant environmental aspects" and to determine whether there are any relevant operational procedures and activities that should be communicated to suppliers and contractors. Unlike other existing EMS standards, ISO 14001 stops short of requiring an organization to police its suppliers and contractors.

Finally, the implementation portion of ISO 14001 requires an organization to make plans for response to accidents and emergency situations and for preventing and mitigating the environmental impacts associated with them. ISO also suggests that the organization test such procedures where "practicable." The meaning of "practicable" is left for the individual organization to determine.

CHECKING AND CORRECTION ACTION

ISO 14001 requires an organization to establish and maintain documented procedures to monitor and measure "key characteristics" of its operation that can have "significant impact" on the environment. The organization also must develop procedures for handling events of nonconformance with the EMS, mitigating environmental impacts, and performing corrective and preventive action. ISO 14001 also suggests that the organization review its documented procedures after any corrective or preventive action is taken.

An organization's records established pursuant to an EMS must be managed. The standard specifies that records that concern training, audit results, and management reviews must be developed and maintained. The records must be of sufficient quality to enable them to be understood, relevant, available, and safe from damage, deterioration, or loss.

The organization also must establish and maintain an audit program to determine conformance with the EMS and provide information on results to management. Required components of the audit program include its scope, its frequency, the audit methods used, a roster of the audit team, and the audit report.

MANAGEMENT REVIEW

"Top management," not otherwise defined by ISO 14001, must collect information on the suitability of its EMS and perform a review. These reviews must be conducted "periodically." The period of such a review is determined by the organization. The purpose of the review is to ensure the adequacy and effectiveness of its EMS.

CONFORMANCE WITH ISO 14001

Conformity assessment guidance and options are under development by ISO and multiple national and regional accreditation bodies in parallel with the development of the EMS standards. ISO 14001 provides two options for conforming with the standard. ISO 14001 recognizes that demonstrating to others a conformance to the standard may proceed through third-party certification or through a self-determination and declaration of conformance with the standard (ISO 14001 Section 1). ISO 14001 contains the self-determination option to allow individual organizations to choose whether and when to share information outside of the organization. However, the common belief is that most organizations will seek third-party registration in an effort to bypass any questions regarding the potential bias of a self-conformance claim.

ISO 14001 is silent on the subject of procedures for determining conformance with ISO 14001. The development of guidelines for conformity assessment is instead under the control of a separate ISO committee. The ISO Conformity Assessment Committee (CASCO) provides guidelines for conformity assessment, which help national accreditation bodies and registrars develop programs for assessing conformity to ISO standards. One of the significant issues to be worked out regarding accreditation is the transboundary use of accreditors. With the late arrival of a U.S.-based accreditation scheme, registration in the United States has occurred through other nationally accredited registration. Will there be a meaningful difference between a U.S. or a E.U. based accreditation scheme? The practical application of the various accreditation schemes bears watching in the future.

CONCLUSION

Since the mid 1980s, industry and government initiatives in environmental management proliferated, which in turn encouraged ISO to produce a multi-stakeholder, international opinion on EMS. Using a consensus approach, ISO has endeavored to prepare a standard on EMS that will be flexible enough to accommodate a variety of organizations operating in a multitude of cultures. The overarching goal for ISO was to provide a document that would encourage the adoption of an EMS, which in turn would promote improved environmental performance. Because ISO 14001 is recently adopted, the use of such a standard bears scrutiny of any company considering its environmental performance.

REFERENCES

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CHAPTER 6

Industrial Marketplace Product Decision Making

MARK EISEN
The Home Depot

As the world's largest building materials retailer, The Home Depot embarked more than 6 years ago on a journey to try to do the right thing and get ahead of the curve when it came to how it believed the environment would affect its business and customers in the future. The informal environmental management system the company created focuses on merchandise as the fulcrum through which the company can most forcefully bring about positive environmental change. The underpinnings of this strategy are to offer the consumer alternative product choices, leading the consumer where possible rather than just meeting a marketplace demand, and to provide the credible information to help inform consumers' about their environmental choices. The results of applying these strategies reveal that the retailer's decision-making processes very closely mirror the consumer's, and that the retailer's role in the supply chain can be a powerful stimulant to enhancing and implementing sustainable production practices.

Anecdotal evidence from our stores shows how the best available tools of environmental decision making—in particular, ecolabeling, product certification, and the life-cycle inventory stage of life-cycle analysis—can be used by retailers and consumers. Most important, we have found that our efforts to link the consumer (including our buyers) to the supply chain are an important catalyst to achieve a sustainable future. Sustainable production is simply not possible without sustainable consumption. As an advanced consumer economy, the United States has a tremendous obligation and opportunity to educate and empower consumers through marketplace and government initiatives to create a "sustainable consumer." The environmental information for forest products and competing commodities—in particular, steel—is still emerging, but it seems clear that the lessons learned from other industries point to a possible tremendous upheaval in building-product markets. This will be particularly true if consumers are conditioned to connect the increasingly negative effects of climate change to their own local environmental health, and then in turn connect their buying choices of wood to their own eventual potential endangerment or demise.

CHAPTER 7

Life-Cycle Assessment for Paper Products

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The Environmental Defense Fund (EDF), in conjunction with a group of major U.S. paper purchasers, recently conducted a life-cycle-based study of various grades of paper. This 28-month effort, called the Paper Task Force, whose members were from Duke University, Johnson & Johnson, McDonald's, The Prudential Insurance Company of America, and Time, Inc., released its final report in December 1995 (Environmental Defense Fund, 1995). The primary intent of the document is to educate an audience of paper purchasers about the environmental (and related economic and performance) consequences of their paper-purchasing decisions and to provide them with steps they can take to increase their purchase and use of environmentally preferable paper.

The technical basis for the environmental preferences identified in the Paper Task Force recommendations is an analysis of environmental impacts associated with the entire life cycle of several major grades of paper, reaching literally from the forest to the landfill. This chapter, which draws heavily on the final report, describes some of the conceptual and methodologic bases of the analysis. It also serves as an illustration of the approach adopted by one of the country's major environmental advocacy organizations to assess the environmental impacts associated with the use of paper and paper products.

WHY ADOPT A LIFE-CYCLE VIEW?

In identifying environmental preferences, the task force adopted a broad, systematic view of the issues involved rather than considering just one or a few attributes of paper—its recycled content, for example, or how it is bleached. The task force constructed a set of analytical tools that allow different types of paper to be compared on an environmental basis across their full life cycles, including how the fiber used to make paper is acquired, whether from a forest or from a recycling collection program; how that fiber is manufactured into a range of paper products; and how those products are managed after use, whether in landfills or incinerators or through collection for recycling. In using this approach, the task force has provided a way for purchasers to address all of the major environmental impacts of their paper use.

This approach to developing a decision framework for buying paper reflects the facts that impacts associated with the use of paper arise from all of the activities indicated above and that a credible environmental comparison of different types of paper must consider all of them—not just a subset. Equally important, a life-cycle approach elucidates steps to reduce environmental impacts at each stage and acknowledges that actions that affect only one or two stages will not produce optimal environmental results.

For example, reducing the use of paper can generally provide major environmental benefits, but even after aggressive use reduction, businesses still use significant quantities. Our analysis documents that using paper with recycled content also provides comparative environmental benefits in the areas of forest management, pulp and paper manufacturing, and solid-waste processing and disposal. However, there are ultimately functional and economic limits to the amount of recycled material that can be used in paper on an aggregate basis. It is important, therefore, to examine opportunities to reduce the environmental impacts associated with the acquisition of virgin fiber through forest management and with the manufacturing of virgin pulp and paper.

CONSIDERING ALL ASPECTS OF FIBER ACQUISITION

Obtaining the fiber to make paper products—whether derived from used paper collected for recycling or from trees—entails a range of environmental impacts. Collection and processing of recovered paper—activities that are typically extensively analyzed in life-cycle studies of paper products—requires energy and can release pollutants to the environment. These consequences must be viewed from a larger perspective, however, one that is typically ignored in life-cycle analyses. By displacing some of the need for virgin fiber and extending the overall fiber supply, recycling can offset the environmental impacts of acquiring virgin fiber as well as those from making virgin paper and disposing of paper after use.

To explain the environmental differences between virgin and recycled-paper production, use, and postuse management, it is necessary to assemble a complete picture. This means not just examining differences in recycled and virgin manufacturing processes and in waste disposal versus material recovery systems, but also considering the "upstream" impacts associated with acquiring virgin fiber from forests. Most studies of paper products, including virtually all life-cycle inventories, draw the upstream boundary of their analyses *after* the forest: In essence, they assume a given quantity of wood as an input into the product system being studied, without considering the environmental consequences of activities required to produce that wood.

To be sure, the biologic and ecologic character of many of the impacts of forest management activities do not allow a direct or quantitative comparison to other measures of environmental impact—for example, energy use or releases of air emissions from a manufacturing facility. Indeed, the omission of forest management issues is usually explained by invoking the difficulty of integrating into the analysis the admittedly more qualitative nature of many such impacts. To omit those impacts entirely from an assessment of paper products, however, produces a greatly distorted picture—one that is systematically biased against paper products that incorporate recovered fiber.

The Environmental Defense Fund chose instead to include a full assessment and description of forest management impacts, and through these recommendations, we have directly integrated the information as a paper-purchasing consideration. Significantly, such information is not only relevant in assessing the relative merits of recycled versus virgin fiber content, but also in identifying environmental preferences among different management practices used to produce virgin fiber.

A critical need in the area of life-cycle assessment methodology as applied to wood as a raw material, therefore, is to develop means for explicitly considering the range of potential and actual environmental impacts associated with forest management practices. These impacts can include damage to forest soils and productivity, water quality and aquatic habitat, plant and animal habitat and diversity, and the preservation of important natural forest communities and ecosystems. The potential consequences of most concern are the cumulative impacts of forest management activities over time and on a scale larger than that of a particular activity conducted in a particular stand of trees—environmental concerns that are particularly far removed from traditional life-cycle analysis methods.

Because an increase in the use of recovered fiber by paper mills means a lower requirement for pulpwood, recycling extends the fiber base and can help to conserve forest resources. Moreover, the reduced demand for virgin fiber achieved through recycling will generally reduce the intensity of forest management required to meet a given demand for paper. In so doing, it can help foster changes in forest management practices that are environmentally beneficial. For example, pressure could be reduced to convert natural forests and sensitive areas, such as wetlands, into intensively managed pine plantations, and more trees could be managed on longer rotations to meet demand for solid wood products rather than fiber.

LIFE-CYCLE INVENTORY METHODOLOGY

The task force compared energy requirements and environmental releases from 100 percent recycled-fiber-based and 100 percent virgin-fiber-based systems. Each system includes analogous activities in the acquisition of fiber, pulp, and paper manufacturing and disposal of residuals. The systems approach allows an assessment of the full range of environmental consequences that follow from the choice to produce recycled-content paper and recover and recycle used paper, as opposed to producing virgin paper, disposing of it and replacing it with new virgin paper.

We recognized that paper often has less than 100 percent recycled content. By comparing 100 percent virgin and 100 percent recycled papers, we sought to assess the relative energy use and environmental releases of each type of fiber arising from its acquisition, manufacture, use, and postuse management by various means. Environmental attributes of paper that contain intermediate quantities of recycled fiber would fall between the estimates provided in this study.

SCOPE OF COMPARISON

For the recycled-fiber-based system, the task force examined used paper collection, transport of the recovered paper to a material recovery facility (MRF), processing of the material at the MRF, transport of processed recovered material to the manufacturing site, manufacturing of pulp and paper using recovered fiber, and disposal of residuals from MRF operations and paper manufacturing.

For the virgin-fiber-based system, we included harvesting of trees and transport of logs (or chips) to the mill, debarking and chipping, manufacture of pulp and paper using virgin fiber, collection of the paper after its use as part of municipal solid waste (MSW), transport of the waste to MSW landfills and waste-to-energy incinerators, and disposal or processing of the waste at such facilities. In the United States, landfilling is used for about 80 percent of the MSW that is not recycled, while waste-to-energy incineration accounts for virtually all of the rest (Franklin Associates, 1994). This 4-to-1 ratio was applied to the landfill- and incinerator-specific data developed in our analysis to estimate energy use and environmental releases associated with aggregate disposal of used paper as part of MSW.

The environmental data gathered by the task force on the recycled and virgin-fiber-based systems included energy use and environmental releases in the form of solid-waste output, releases in several categories of air emissions and waterborne wastes, and water use–effluent flow in manufacturing (Table 7-1).

Our methodology for two specific categories of environmental parameters—energy use and emissions of greenhouse gases—merits further elaboration. In examining energy use, we considered total energy, that generated from combustion of all types of fuels, including fuels derived from wood byproducts (bark and pulping liquors at pulp mills and paper in incinerators). We also examined the subset of energy purchased from electric utilities and from combustion of purchased fossil fuels (that is, excluding combustion of wood-derived materials). The analysis incorporates environmental releases and solid-waste generation as-

TABLE 7-1 Environmental parameters examined for the recycled- and virgin-fiber-based systems

Solid Waste	Energy Usage	Air Emissions	Waterborne Wastes
Total	Total	Total greenhouse gases	Adsorbable organic halogens[a]
	Purchased	Net greenhouse gases	Biochemical oxygen demand
	Fossil fuel derived	Nitrogen oxides	Chemical oxygen demand
		Particulates	Suspended solids
		Sulfur oxides	Effluent quantity—water use[a]
		Hazardous air pollutants[a]	
		Volatile organic chemicals[a]	
		Total reduced sulfur[a]	

[a] For manufacturing processes only.

sociated with the operation of power plants that produce electricity used in recycled and virgin manufacturing processes.

Purchased electricity can be generated from a variety of sources, including fossil fuels (coal, oil, natural gas), nuclear power, and hydropower—each of which has its own set of associated environmental impacts. Nationally, about 68 percent of electricity is produced from combustion of fossil fuels (U.S. Environmental Protection Agency, 1992). In our analysis, therefore, we also indicate the fraction of purchased energy used in the virgin and recycled systems that is derived from fossil fuels. The relative consumption of fossil fuels by the different systems is important. Consumption of fossil fuels contributes to the depletion of a natural resource, and fossil fuel extraction and transportation can damage natural resources through mining activities (for example, strip-mining for coal) and accidental releases of raw fuels or other pollutants to the environment (for example, oil spills, refinery explosions, leaks from natural gas pipelines). Fossil fuel extraction, refinement, and combustion also require energy and entail releases to the environment; estimates of these factors are incorporated directly into our quantitative analysis.

The difference between total and purchased energy used by a system represents the amount of energy generated from wood-derived fuels (bark, pulping liquors, and used paper). For several paper grades we examined, the virgin-fiber-based system uses more total, but less purchased, energy than does the recycled-fiber-based system. Such a system consumes less fossil fuel and hence entails fewer of the environmental impacts just described, but it also consumes more wood resources, and this has the environmental implications with respect to forest management discussed earlier.

Our accounting for greenhouse gases—specifically, CO_2 and methane emissions—also requires some elaboration. The environmental concern associated with such emissions is their association with the greenhouse effect, linked to global climate change. In assessing these emissions, we compared the virgin and recycled systems with respect to both *total* and *net* greenhouse gas emissions. (We did not include emissions of nitrous oxide in our estimate of greenhouse gas emissions, because of a lack of data for most of the activities involved in the paper systems we examined. We also made a judgment that, despite the high potency of nitrous oxide, actual emissions would be so small as to make their contribution to the total minor.) Carbon dioxide and methane emissions are accounted for somewhat differently.

Emissions of CO_2 derived from burning wood-derived materials (bark and pulping liquors in pulp and paper mills, and paper in incinerators) do not result in a *net* increase in such emissions, because the trees from which these materials were derived absorbed the equivalent amount of CO_2 in the process of growing. (Other activities involved in growing trees that could result in net emissions of CO_2 are not included here. Examples are soil disturbance associated with preparing a site for tree planting and energy or materials used in the production of fertilizers and other chemicals used in forests.) In contrast, emissions of CO_2 derived from the combustion of fossil fuels do result in a net increase. Hence, wood-derived CO_2 emissions are counted in *total*, but not *net*, greenhouse gas emissions; fossil-fuel-derived CO_2 emissions are counted in both *total* and *net* greenhouse gas emissions.

Landfills are the only significant source of methane emissions in our systems comparison. (Methane emissions also are generated in the production and transport of petroleum and natural gas. Our examination of the magnitude of these releases indicates they are minor in comparison to landfill methane.) Decomposition of paper-based materials in landfills results in emissions of both CO_2 and methane. The CO_2 emissions are accounted for as just described. They contribute to *total* but not to *net* greenhouse gas emissions, because they are offset by an equivalent amount of CO_2 originally absorbed by the trees from which the paper is made. However, emissions of methane must be accounted for differently. Methane is a much more potent greenhouse gas than is CO_2, with one pound of methane emissions representing the equivalent of 69 pounds of CO_2. The 69-to-1 ratio is a mass-based comparison, and corresponds to the more commonly reported 25-to-1 ratio as measured on a molecule-to-molecule basis; the difference in the two ratios is due to the higher molecular weight of CO_2 relative to methane (Franklin Associates, 1994). Each pound of methane contributes 69 pounds of greenhouse gas emissions *when expressed as* CO_2 *equivalents*. Only one pound of these emissions was derived from CO_2 originally absorbed by the trees used to make the paper; hence, all 69 pounds are counted in *total* greenhouse gas emissions; 68 pounds are counted as *net* greenhouse gas emissions. Both *total* and *net* greenhouse gas emissions are expressed in terms of CO_2 *equivalents*.

Except for energy use in harvesting trees and transporting logs, the environmental effects associated with obtaining virgin fiber from trees are not considered in this life-cycle inventory (or in others), because of their largely qualitative nature. As discussed earlier, intensive management of forests for fiber and wood production can have significant consequences, such as effects on biodiversity, wildlife habitat, and natural ecosystems. Such consequences are an important difference between recycled-fiber- and virgin-fiber-based systems.

ILLUSTRATIVE RESULTS

The task force compiled data for several grades of paper and paperboard products: newsprint made using either virgin thermomechanical pulp (TMP) or recovered deinked newspapers; corrugated boxes made using either virgin unbleached kraft linerboard and semichemical medium or recovered corrugated boxes; office papers made using either virgin uncoated freesheet or recovered deinked office paper; and paperboard used in folding cartons made using either virgin pulp (coated unbleached kraft or solid bleached sulfate) or nondeinked recovered paper.

As an example to illustrate both the scope and the results of our analysis, Figures 7-1 and 7-2 and Table 7-2 present the data for newsprint. Figure 7-1 shows the energy use associated with each component activity within the recycled- and virgin-fiber-based systems. Figure 7-2 summarizes the data for all of the environmental parameters we examined, summing them across all of the activities within a given system, and then comparing the totals for the *recycled production plus recycling* system to those for a composite *virgin production plus waste management* system that incorporates data from the two virgin systems involving landfilling and waste-to-energy incineration.

This comparison of the recycling-based system to the *composite* waste-management-based system is ultimately the most useful environmental comparison, for two reasons. First, in contrast to their ability to assist directly in the recycling of paper they use, users of paper have no ability to determine how their paper is managed after discard if it enters the waste stream. Whether such paper is destined for disposal in a landfill or for processing at an incinerator is a function of many factors outside the control of the paper user: the local availability of the two options, their relative economics, the nature of the collection system, and so on—all factors that can change over time. Second, we are most interested in assessing the most typical or representative case associated with management of discarded paper. On average across the nation, about 80 percent of used paper that is not recycled will be landfilled, and about 20 percent will be incinerated. Using this 4-to-1 ratio to calculate a weighted average of the landfill- and incinerator-specific data developed in our analysis allows us to estimate the *average* energy use and environmental releases associated with management of used paper that is not recycled and becomes part of the waste stream.

Table 7-2 gives the detailed data for each parameter and each component activity of the recycled and the two virgin-fiber-based systems.

The task force's analysis showed clear and substantial environmental advan-

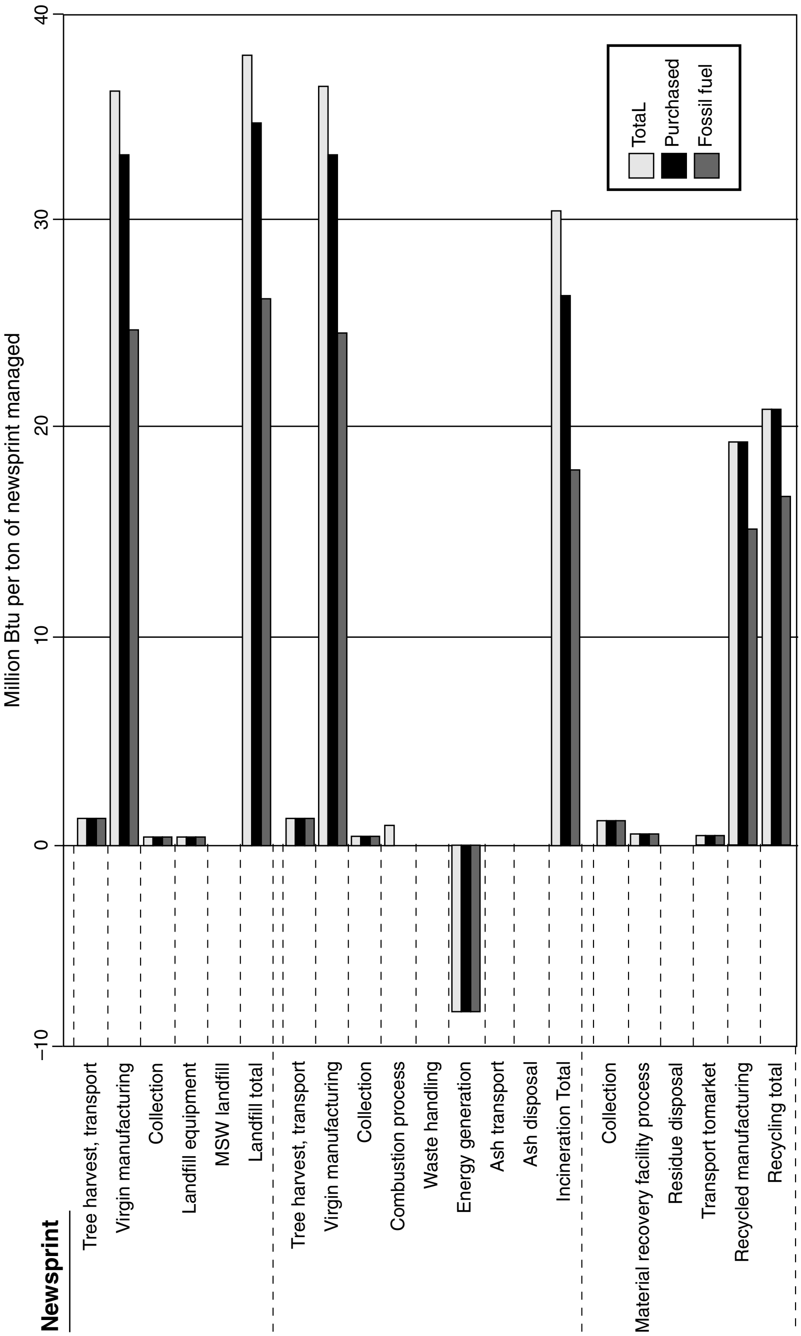

FIGURE 7-1 Total, purchased, and fossil fuel energy use for component activities of paper production and management.

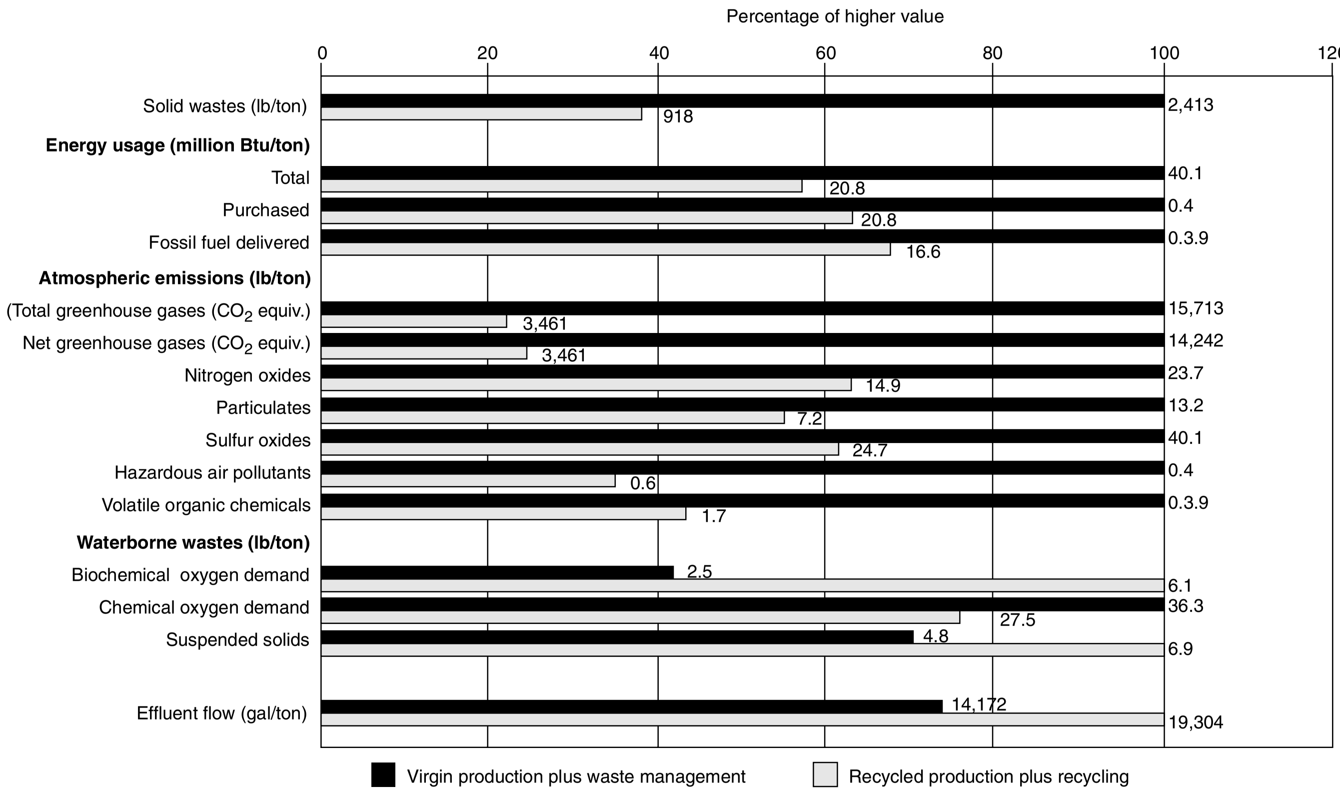

FIGURE 7-2 Average energy use and environmental releases for managing newsprint by recycled production + recycling vs. virgin production + waste management (landfilling and incineration).

tages from recycling all of the grades of paper we examined. For each grade, and for most of the parameters examined, a system based on recycled paper production plus recycling results in comparable or smaller energy use and environmental releases than does a system based on virgin production plus waste management.

There are several exceptions to this general finding. Among the most interesting is that, although all of the recycled-fiber-based systems require smaller amounts of *total* energy than do the virgin-fiber-based systems, for three of the five grades examined here (office papers, corrugated boxes, and coated unbleached kraft paperboard used in folding cartons) the virgin-fiber-based system requires less purchased (and fossil-fuel-derived) energy. Hence, recycling of these grades poses a tradeoff between greater use of fossil fuels and greater use of forest resources.

The strong environmental advantages attributable to recycling hold true despite the exclusion from the model, because of a lack of data, of several types of energy use and environmental releases associated only with the virgin system. These include, for example, the energy and environmental releases associated with forest management other than harvesting; releases to the air and water from landfills other than CO_2 and methane emissions; releases to the air from incinerators other than CO_2, sulfur oxides, nitrogen oxides, and particulates; and releases from ash landfills. Our analysis did not include releases from disposal facilities used for residuals from either the virgin- or the recycled-fiber-based systems.

In addition, assumptions were made in the model that overestimate energy use and environmental releases for the recycling system. Because of greater availability of data, our quantitative comparison is based on collection of recovered paper through residential curbside collection programs. We recognize that other systems (drop-off centers and collection from commercial sources) constitute most of total paper recovery. This assumption of curbside collection overstates the energy use and associated environmental releases associated with collection of paper, especially for grades such as corrugated containers and office paper that are collected largely from commercial sources through more efficient systems. Similarly, our analysis includes processing of recovered paper at material recovery facilities. Because some recovered paper, especially that from commercial sources, bypasses such intermediate processing and can be delivered directly to the mill, this assumption, too, probably overstates energy use associated with the recycling option.

Several other specific results from the comparison are worth noting, because they run somewhat counter to commonly-held perceptions about recycling.

Energy Use in Transportation Versus Manufacturing

It is often noted that collection and transport of materials for recycling requires more energy and hence generates larger releases of pollutants from vehicles than does collection of municipal solid waste for disposal in landfills or

TABLE 7-2 Energy, air emissions, solid waste outputs, waterborne wastes, and water use associated with component activities of three methods for managing newsprint

	Virgin Production, Landfilling					
	a	**b**	**c**	**d**	**e**	**f**
[Notes]	Tree harvesting/ transport	Virgin mfctr' ing energy/ releases	Utility energy/ releases [7]	Collection vehicle & landfill equipment	MSW landfill [1]	Total (per ton ONP landfilled)
Energy usage (000 Btus/ton)						
Total	1,150.0	36,300.0		527.4		37,977.4
Purchased	1,150.0	33,000.0		527.4		34,677.4
Fossil fuel-derived	1,150.0	24,624.6		527.4		26,302.0
Environmental releases (lbs/ton)						
Atmospheric emissions						
Total greenhouse gases (CO_2 equivalents) [9]	183.8	5,946.0		84.1	11,626.7	17,840.5
Net greenhouse gases (CO_2 equivalents) [10]	183.8	5,300.0		84.1	11,152.0	16,719.9
Nitrogen oxides	2.2	21.1		1.0		24.3
Particulates	0.49	13.1		0.23		13.8
Sulfur oxides	0.31	41.4		0.14		41.9
Hazardous air pollutants[8]		0.43				0.43
Volatile organic chemicals (8)		3.9				3.9
Solid wastes	0.6	362.0	444.2	0.26	2,000.0	2,807.0
Waterborne wastes						
Biochemical oxygen demand	0.0008	2.5	0.0024	0.0003		2.5
Chemical oxygen demand	0.0031	36.3	0.0073	0.0016		36.3
Suspended solids	0.0008	4.8	0.0048	0.0003		4.8
Effluent flow (gals/ton)[8]		14,172				14,172

NOTES:

(1) Landfill gas collected for energy recovery not included.
Only CO_2 and CH_4 in landfill gas are included in atmospheric emissions; CH_4 has been converted to CO_2 equivalents using a molecular ratio of 25:1 and a weight ratio of 69:1.
Waterborne wastes caused by leachate from landfills not included.

(2) Air emissions based on new source performance standards (NSPS) for combustors >250 tpd.

(3) Values in parentheses represent energy and environmental releases from a utility avoided due to energy generation by incineration.
Assumes 670 kWh of electricity generated by a utility is avoided by combusting 1 ton of ONP.
Avoided releases based on fuel mix for national electricity energy grid.

(4) Waterborne wastes caused by leachate from ash landfills not included. Assumes burning ONP yields 9% ash residue by dry weight, 25% moisture content as disposed.

(5) Assumes curbside collection of ONP.

Virgin Production, Incineration

a	b	c	d	e	f	g	h
Tree harvesting/ transport	Virgin mfctr'ing energy/ releases	Utility energy/ releases [7]	MSW collection	W-T-E combustion process [2]	Avoided utility energy/ releases [3]	Ash landfill disposal [4]	Total (per ton ONP combusted)
1,150.0	36,300.0		296.6	782.8	(8,202.0)	35.6	30,363.0
1,150.0	33,000.0		296.6	33.0	(8,202.0)	35.6	26,313.2
1,150.0	24,624.6		296.6	33.0	(8,202.0)	35.6	17,937.8
183.8	5,946.0		47.3	2,207.1	(1,024.8)	5.7	7,365.0
183.8	5,300.0		47.3	5.3	(1,024.8)	5.7	4,517.2
2.2	21.1		0.57	1.8	(4.7)	0.07	21.1
0.49	13.1		0.13	0.27	(3.4)	0.02	10.7
0.31	41.4		0.08	0.39	(8.8)	0.01	33.4
	0.43						0.43
	3.9						3.9
0.6	362.0	444.2	0.15	180.0	(122.6)	0.02	864.3
0.0008	2.5	0.0024	0.0002		(0.0007)	0.0000	2.5
0.0031	36.3	0.0073	0.0008		(0.0019)	0.0001	36.3
0.0008	4.8	0.0048	0.0002		(0.0014)	0.0000	4.8
	14,172						14,172

table continues on next page

(6) Assumes ONP is processed at a material recovery facility (MRF); values based on average of low-tech and high-tech MRF.

(7) Values represent the solid waste and waterborne wastes associated with utility generation of electricity purchased by the virgin or recycled pulp and paper mill; energy and air emissions have been incorporated into the adjacent manufacturing energy/releases column. Releases incurred are based on fuel mix for national electricity energy grid.

(8) Values for this parameter are reported by the cited sources only for the virgin and recycled manufacturing processes.

(9 Total greenhouse gases include CO_2 emissions from combustion of both wood-derived materials (including paper) and fossil fuels, as well as CO_2 and CH_4 emissions from landfills.

(10) Net greenhouse gases include CO_2 emissions from combustion of fossil fuels and CH_4 emissions from landfills.

TABLE 7-2 *Continued*

	Virgin Production, Recycling						
	a	**b**	**c**	**d**	**e**	**f**	**g**
[Notes]	ONP collection [5]	MRF process [6]	Residue landfill disposal	Transportation to market	Utility energy/ releases [7]	Recycled mfctr'ing energy/ releases	Total (per ton ONP recycled)
Energy usage (000 Btus/ton)							
Total	989.0	282.7	42.2	205.2		19,300.0	20,819.1
Purchased	989.0	282.7	42.2	205.2		19,300.0	20,819.1
Fossil fuel-derived	989.0	282.0	42.2	205.2		15,088.1	16,606.5
Environmental releases (lbs/ton)							
Atmospheric emissions							
Total greenhouse gases (CO_2 equivalents) [9]	157.7	31.7	6.7	33.0		3,232.0	3,461.1
Net greenhouse gases (CO_2 equivalents) [10]	157.7	31.7	6.7	33.0		3,232.0	3,461.1
Nitrogen oxides	1.9	0.17	0.08	0.28		12.4	14.9
Particulates	0.43	0.11	0.02	0.05		6.6	7.2
Sulfur oxides	0.27	0.29	0.01	0.06		24.1	24.7
Hazardous air pollutants[8]						0.15	0.15
Volatile organic chemicals (8]						1.7	1.7
Solid wastes	0.49	163.8	0.02	0.10	223.4	530.0	917.8
Waterborne wastes							
Biochemical oxygen demand	0.0006	0.0002	0.0000	0.0002	0.0012	6.1	6.1
Chemical oxygen demand	0.0030	0.0005	0.0001	0.0006	0.0037	27.5	27.5
Suspended solids	0.0006	0.0000	0.0000	0.0002	0.0024	6.9	6.9
Effluent flow (gals/ton)[8]						19,304	19,304

incinerators. Our analysis is consistent with this finding, but it also shows that both of these energy uses (and their contribution to environmental releases) are quite small compared with the energy used in manufacturing (see Figure 7-1 for the case of newsprint). Indeed, for all grades of paper and for virgin- and recycled-fiber systems, manufacturing energy is the predominant use of energy, by a large margin. Materials and residuals collection, processing, and transport are all relatively small by comparison. Moreover, the reduction in total manufacturing energy consumption resulting from using recovered paper rather than virgin materials is much larger than the increase in energy required for collection and transport of recovered materials relative to municipal solid waste.

Tree Harvest, Transport Energy Versus Recycling Collection

Another factor often neglected in assessing virgin-fiber-based systems involves the amount of wood in the form of trees that must be harvested and transported to serve as a source of raw material. Wood in harvested trees contains approximately 50 percent moisture. In addition, wood pulping processes have yields that are considerably less than 100 percent; bleached kraft pulping yields are about 45 percent, unbleached kraft yields are about 57 percent and mechanical pulp yields are 80–95 percent. The combination of these factors means that from 2 tons to as many as 3.5 tons of trees must be harvested to produce 1 ton of pulp. The harvesting and transport energy per ton of pulp, therefore, is relatively high even compared with recovered paper collection and transport (see Figure 7-1 for newsprint).

Greenhouse Gas Emissions

Despite the greater use of fossil-fuel-derived energy by several of the recycled-fiber-based systems relative to their virgin counterparts, all of the recycled-fiber-based systems generate far lower emissions of both total and net greenhouse gases. This is because the primary means of managing waste paper is through landfilling. Incineration of waste paper does not generate net greenhouse gas emissions, because the carbon present in the paper that is released as CO_2 upon combustion represents CO_2 that was originally absorbed by growing trees. Indeed, energy generation from such incineration offsets net greenhouse gas emissions from electric utilities. However, much of the carbon present in landfilled waste paper decomposes anaerobically to produce methane, which is a far more potent greenhouse gas (69-fold, on a mass basis) than is the CO_2 that was originally absorbed. In essence, a decision not to recycle paper means that most of it will be landfilled, and much of that paper will anaerobically decompose to produce methane—thereby greatly amplifying the virgin-fiber-based system's contribution to greenhouse gases.

IMPORTANT CAVEATS

All details of the task force's model, data and assumptions are included in the full report. Some important caveats should be kept in mind when considering the findings just presented.

In general, the data cited and presented represent average (mean) values, or estimates, intended to be representative of the facilities and activities being characterized, and the comparisons will be valid only for "typical" activities or facilities. Because of the time- and site-specific variation in much of the data presented, caution should be exercised in applying these average data to characterize the environmental attributes of individual facilities or activities. The environmental characteristics of the activities and facilities examined in this type of analysis will virtually always show considerable variation. Average data can therefore overstate or understate the magnitude of a given environmental parameter for a specific activity or facility. Although the data presented are useful in indicating general or likely attributes, they should be subjected to further examination and confirmation if they are to be used in a more specific manner or setting than intended.

No attempt was made to assess the magnitude of actual environmental impacts that arise from the energy use and environmental releases; only their quantity was reported. Actual impacts depend on site-specific and highly variable factors, such as rate and location of releases, local climatic conditions, population densities, and so on, which together determine exposure to substances released to the environment. Such an assessment would require a detailed analysis of all sites where releases occur, which was well beyond the scope of this project (and indeed virtually any analysis of this sort). Our comparison was of necessity limited to a quantitative comparison of data on the magnitude of energy use and environmental releases associated with the systems examined.

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CHAPTER 8

Consumer Acceptance of Environmental Labeling on Wood Products

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Consumer acceptance of environmental labeling on wood products depends largely on the source of the environmental claim and on the information communicated to the buyer by the label. This chapter discusses the results of consumer survey research on environmental labeling, provides an example of labeling currently used on wood products in the marketplace, and describes an emerging labeling option.

CONSUMER RESEARCH

Research conducted during the past decade has shown that consumers are interested in receiving accurate, accessible environmental information on product labels but that they are skeptical about environmental claims. Studies also indicate increased consumer acceptance of environmental claims that have been independently verified by a credible, scientific source.

A review of the research reveals examples of consumer distrust of environmental claims made by manufacturers:

- A 1990 environmental report cited 47 percent of consumers as dismissing environmental claims as "mere gimmickry" (Environmental Protection Agency, 1993).
- A 1992 study by the Hartman Group reported that only 13 percent of respondents believe corporations are "trustworthy sources of information about environmental matters" (Hartman Group, 1992).
- Hardware industry research found that only 11 percent of consumers surveyed believe that businesses can be trusted to "do the right thing most of the time" for the environment (Mueller Hardware Research Foundation, 1992).

At the same time, other studies show consumer support for labeling and market demand for products with environmentally friendly attributes:

- A 1991 NBC News and *Wall Street Journal* survey found that 53 percent of consumers avoid purchasing products because of environmental concerns (Mueller Hardware Foundation, 1992).
- That same year, a report published by J. Walter Thompson found that 91 percent of consumers polled favor "labeling products which are environmentally safe to help people make smart buying decisions (Thompson, 1991).
- A 1992 *Advertising Age* survey reported that 73 percent of respondents believe that environmental marketing claims "sometimes or very often influenced their purchasing decisions"; 60 percent said they are now "more likely to buy a product because of its environmental claims than they were three years earlier" (Environmental Protection Agency, 1993).
- A Roper/Starch survey in 1994 reported that nearly half of U.S. consumers have purchased "green" products, representing a 70 percent increase since Roper began collecting such statistics in 1990 (Roper/Starch Survey, 1994).
- A *Good Housekeeping* study found that 93 percent of American women believe that an independent environmental label would be "very or somewhat useful"; while 82 percent said that they would be more likely to buy products that displayed an independent mark of certification than products that did not (Good Housekeeping Institute, 1990).

Surveys conducted in the forest products industry have noted similar findings. In 1992, the Western Wood Products Association conducted a survey of building industry wholesalers, retailers, and professionals. Seventy-one percent of respondents indicated that scientific information on the environmental impacts of wood versus other building materials would be useful to them; 70 percent expressed interest in lumber from "an envirocertification program endorsed by a third-party scientific audit (Western Wood Products Association, 1993).

INTERNATIONAL STANDARD-SETTING INITIATIVES

"Ecolabeling" and certification also have become topics of interest around the world. The International Organization for Standardization (ISO) has taken up the challenge of establishing guidelines for environmental claims and claims verification through its Technical Committee on Environmental Management (TC 207).

Thus far, ISO has defined three classifications of ecolabels that present environmental claims to consumers. Type I labeling involves establishing multiple environmental criteria for products in specific categories and the issuance of a seal to applicants meeting those criteria. Examples include the German Blue Angel, the Nordic Swan, and the Japanese Eco-Mark. Labels that claim specific product attributes, such as the percentage of recycled material in a product or its biodegradability, are Type II labels. Type III labels present the environmental performance of a product based on a life-cycle assessment. Proposals within ISO to introduce certification and labeling guidelines for wood products based on forest management claims have been unsuccessful to date.

The Forest Stewardship Council (FSC) was established by representatives in the environmental movement and in industry to promote sustainable forest management worldwide through the certification and labeling of timber from well-managed forests. The council establishes principles and criteria for forest management and accredits certifiers of forest products. It also works with government entities to develop national forestry standards for certification. Buyers groups have been formed by manufacturers and retailers to support the procurement of wood products from well-managed forests that have been evaluated by FSC-accredited certifiers.

Although the drafting of FSC and ISO standards has occurred after the emergence of marketplace labeling initiatives, the guidance of these organizations should help increase label credibility, both domestically and abroad.

ACCEPTED AND EMERGING OPTIONS

Scientific Certification Systems, Inc. (SCS), an independent testing and certification organization based in Oakland, California, has introduced two certification and labeling options for wood products.

The SCS Forest Conservation Program evaluates and certifies forestry operations and issues a label certifying a well-managed forest claim. Certified forest products companies and the downstream manufacturers and retailers of certified wood products may use the label to market their products. The SCS Certified Eco-Profile program allows producers of wood products to communicate comprehensive cradle-to-grave environmental information in an ISO Type III label format. This program evaluates wood products in particular applications. For example, the Eco-Profile label can be used to inform consumers about the specific environmental effects of wood used as a structural building material.

FOREST CONSERVATION PROGRAM

The SCS Forest Conservation Program evaluation is structured around three elements that encompass technically sound and socially responsible forest stewardship: timber resource sustainability, forest ecosystem maintenance, and financial and socioeconomic considerations. Clearly, exemplary forest stewardship entails more than sustained timber production. Equally important are the extent to which the integrity of the forest ecosystem is maintained and the extent to which the operation can be sustained over the long term. To be certified, an operation must meet or exceed threshold standards in each of the three program elements.

The evaluation of timber resource sustainability measures the extent to which past and current timber management practices have and will yield continuous timber production over the long term. Examples of specific criteria included in the examination are

- harvest regulation,
- pest management strategies,
- harvest efficiency,
- stocking and growth control,
- forest access, and
- product use.

The forest ecosystem maintenance component measures the impact of forest management practices on critical ecosystem elements, such as wildlife habitat and watersheds. It includes an assessment of

- forest structure and composition,
- wildlife management policies and activities,
- pesticide use practices and policies,
- long-term productivity,
- watercourse management policies and activities, and
- ecosystem reserve policies.

Financial and socioeconomic measurements appraise the benefits realized by the community and the economic stability of the forest operation. Criteria under this program element encompass

- financial performance and ownership structure,
- public use management,
- employee training and education,
- community and public involvement,
- investment of capital, and
- employee and contract relations.

Evaluations are conducted according to structured protocols using an interdisciplinary scientific team (forester, ecologist, sociologist, or forest economist) with recognized regional expertise. The forest management audit process defines areas of management strength and deficiency, establishes baseline performance, and delineates where companies can make environmental improvements. The weighting of evaluation criteria in importance and the selection of performance indicators are based on site-specific conditions and allow for regionalization in the programmatic analysis. The data-gathering process encompasses collection of on-site empirical data, an examination of the landowner's plans and documents, and a review of published data sources. Interviews with local, state, or federal forestry agencies and members of the community also are conducted.

The evaluation process has been structured to be as objective as possible in defining and quantifying sustainable forest management. Each criterion within each program element is assigned a score by the evaluation team. The weighted scores are averaged to yield a final score for each program element. Assessments can be duplicated in time and place and the assessment methodology has been confirmed through technical reviews of each assessment by independent experts. Forest operations scoring above 80 points on a 100-point scale in all three program elements earn "Well-Managed Forest" certification.

Participants in the Forest Conservation Program benefit from the information derived from program audits and have improved forest management practices as a result. Improved forest management stands alone as the most important achievement of certification. However, certification also allows forest products companies to demonstrate accountability to wood products manufacturers, retail buyers, consumers, and government policy makers. Certification supports forest products companies in their efforts to communicate, educate, and inform.

In addition to its Well-Managed Forest certification for forest products companies, SCS developed a secondary certification for the downstream manufacturers and retailers of wood from certified forests. By putting specific inventory controls in place, these companies receive "Chain-of-Custody" certification, assuring customers that the wood can be traced to the certified forest source. To date, the Forest Conservation Program has awarded nine Well-Managed Forest certificates and issued 20 Chain-of-Custody certificates.

CONSUMER ACCEPTANCE

Consumer acceptance of the Well-Managed Forest certification label can be demonstrated in part through marketplace successes. Although there is not enough certified product yet available for a reliable statistical analysis, anecdotal information indicates that certified producers have opened new markets and obtained premium prices for their wood products. These successes extend to secondary manufacturers and retailers of certified forest products, and they cut across all market segments for wood products—from home center retailers and commodity dealers, to architecture and design firms, to value-added product manufacturers.

The Collins Pine Company, headquartered in Portland, Oregon, directly attributes to certification sales increases of 25 percent to retailers, 22 percent to furniture manufacturers, and 3–4 percent to commodity dealers. Costa Rica-based Portico gained customers through its certification among home centers and retailers, and increased its market share by nearly 30 percent in 1994 alone. Certification allowed the Seven Islands Land Management Company of Maine to leapfrog beyond sales into primary milling and tap secondary manufacturing through Chain-of-Custody certifications. The company has essentially achieved a vertical integration without making additional investments in downstream facilities. It now receives a 10 percent premium on certified logs and a 5 percent premium on the end-value of products such as shingles.

FIGURE 8-1 Forest Conservation Program label.

Each of these participants integrates the Well-Managed Forest certification label into product brochures and marketing materials. Collins Pine's CollinsWood carries the label directly on the lumber. Figure 8-1 is an example of a Forest Conservation Program label.

Certified Eco-Profile Labeling

The Certified Eco-Profile label (Figure 8-2) was developed by SCS to provide consumers with cradle-to-grave environmental information based on life-cycle assessments. It is similar to a nutritional label, providing a comprehensive summary of a product's environmental performance. Wood products evaluated under this program would be labeled for particular applications, such as use as structural building materials.

Certified Eco-Profile labeling has been recognized within ISO as a unique approach that is now being standardized as a Type III label. In addition to the SCS initiative in the United States, ISO activities have spawned Type III programs in Canada and Sweden. Certified Eco-Profile labels displayed on products have been positively received by consumers thus far.

One important distinguishing feature of the Certified Eco-Profile label is its basis in life-cycle analysis. Because the methodology is being standardized, it creates a uniform basis for presenting environmental information on the Type III label. The ISO subcommittee has suggested principles and guidelines to harmonize the use of life-cycle analysis for making claims about the environmental performance of a product. First, results should not be reduced to a single score. The variety of the variables examined in life-cycle analysis and their inherent differences make them incapable of homogenization. Second, before any comparative claims can be made between one product and another, a life-cycle impact

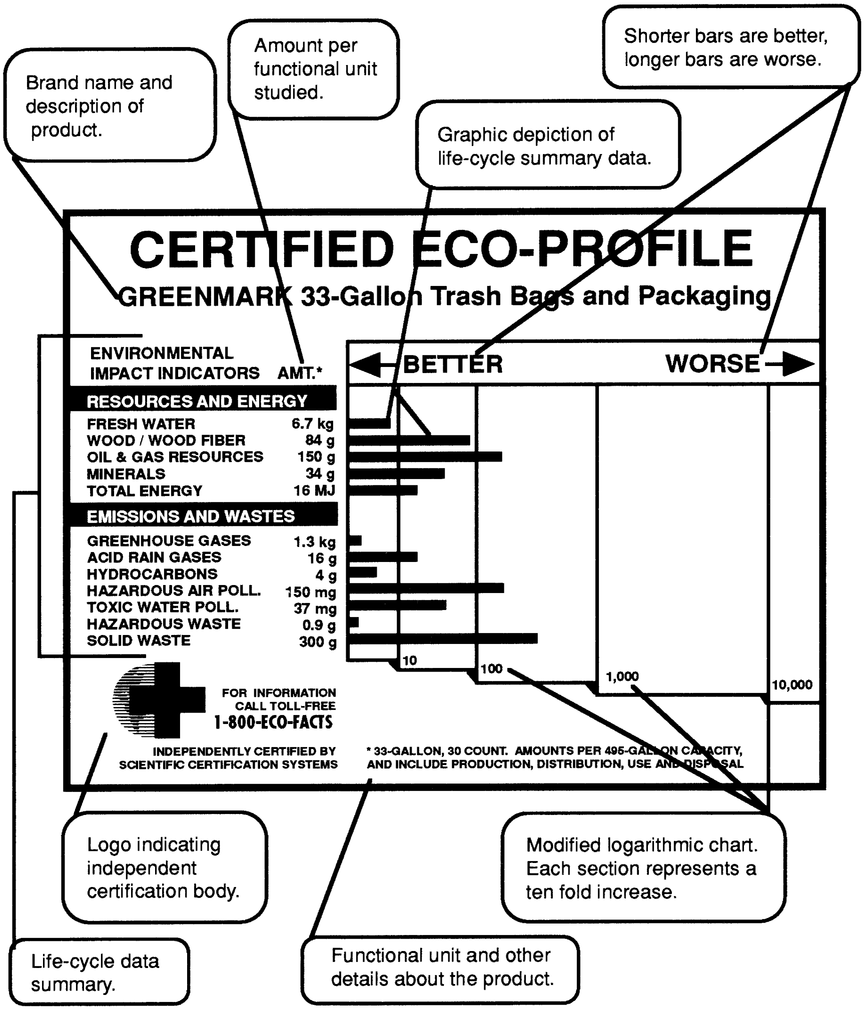

FIGURE 8-2 Eco-Profile label.

assessment should be performed, and the equivalence and functional performance of the products being compared should be established. The specific methodology used to support the Certified Eco-Profile is discussed in Appendix 1 to this volume and is adapted from ISO/TC 207/SC 5/WG 4 N 47.

Using the Label

The Certified Eco-Profile label was designed to provide a clear representation of a given product's environmental profile, along with the numerical infor-

TABLE 8-1 ISO Type III label performance indicators

Resources and energy	Emissions and wastes
Fresh water	Greenhouse gases
Wood and wood fiber	Acid rain gases
Oil and gas resources	Hydrocarbons
Ecosystem depletion	Hazardous air pollutants
Minerals	Ozone-depleting pollutants
Total energy	Toxic water pollutants
Hazardous waste	Solid waste

mation needed by consumers to make detailed comparisons between products. To fulfill ISO Type III labeling objectives, it summarizes life-cycle findings in up to 14 separate environmental performance indicator categories. Indicators fall into two general groups: "Resources and Energy" and "Emissions and Wastes" (Table 8-1). The units of measurement for each indicator are adjusted to avoid overemphasizing or underemphasizing certain data.

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CHAPTER 9

Environmental Impact Assessment Applied to Decision Making

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The topic of environmental impact assessment applied to decision making is a greater challenge when it involves a whole product system interacting with the ecosystem that provides the raw material. The challenge in this chapter is twofold: first, to present the topic in a way that covers its breadth and depth—the diversity of assessment applications across the product system, the specific disciplines developed for such applications, and their limitations. The second element of the challenge is to stress the role of impact assessments in helping decision making strike the proper balance with many other factors in decision making—economics, product functionality, sustainable development, cultural values and others.

DECISION-MAKING AREAS

In a wood product system, including the wood as raw material, there are three important areas of decision making to address: forest management, product preferability, and general issues of sustainability and "ecoefficiency." They are broad enough not to be labeled as endpoints for assessment but rather as decision-making areas. For the past two or three years forestry management and certification issues have been debated worldwide. Likewise, efforts to assign preferability or superiority to products via labels or to regulate preferential purchases are very much alive. General issues of sustainable development and "ecoefficiency" are gaining impetus in decision-making sectors. In the product system, the emerging concept of extended product responsibility is one example of impact assessment applied to decision making.

COMMUNICATIONS AND COMMON SENSE

It is important not to lose perspective in the discussion. Despite the improvements made in the field of impact assessment, the fact remains that decisions must be made, and are being made, in the face of uncertainty, and that there must be a balance between different and sometimes competing factors. My company, Georgia-Pacific, strives to balance shareholders' demands for superior financial returns with society's desire for a clean and sustainable environment. It is natural that we are actively involved in developing and applying different assessment methodologies to help our decision making in all links of the chain of our product system. More accurate information reduces uncertainty, which in turn helps in decision making and in communicating to other stakeholders the preferred alternatives and solutions.

Common sense and good communications help advance projects where the exact cost–benefit ratio or the assessment of impacts are not completely clear. Some decisions made by Georgia-Pacific and others in the complex area of forest management are offered as examples. The need to protect bald eagle nesting areas in Maine, the red-cockaded woodpecker in the Southeast, and the coho salmon and the steelhead trout in the Pacific Northwest were included in our decisions made as part of good management practices. Our joint effort with the Nature Conservancy to manage and protect 21,000 acres along the lower Roanoke River in North Carolina is another example of decision making through good communication, acceptable information, and good common sense.

All of these projects are essentially the result of identified sources of harm for the species which likelihood make them potential risks. They fit well in the forest management decision-making area mentioned above.

In these projects, the impact assessment and subsequent decision making were done, for each specific ecosystem, through a clear communication process. This process allowed for the identification of the ecologic endpoint—protection of wildlife or of endangered species. Assessment of the potential risk in doing nothing was part of the ultimate decision. Our company's employees, university researchers, and representatives of government and interest groups reached a consensus on a decision about these initiatives. In all honesty, we did not have, and yet do not, a tool that would have indicated to us which one was the best project or that would delineate the magnitude of benefits in carrying each of them. Essentially, they all make good sense to us and to our partners.

This volume does not focus on the forest as the source of raw material. It does focus on the product system—wood as raw material, its industrial uses, its products, and its consumption. As such, any portion of this chapter on impact assessment for decision making must address the different assessment tools and applications available for each major element of the product system.

ENVIRONMENTAL IMPACT ASSESSMENTS

No environmental decision, whether made by a corporation or by a national policy body, can be based solely on the results of an environmental impact assessment—regardless of the advanced stage of the methodology used. Many other factors will impact the final decision. These realities were recognized more than 25 years ago when Congress enacted Public Law 91-190, the National Environmental Policy Act (NEPA), in 1969 (National Environmental Policy Act of 1969). NEPA was perhaps the best first example of environmental leadership and concern for sustainable development from any country in the world. Among NEPA's specific ends, it demands balancing the protection of the environment with the use of resources in a manner that will permit high standards of living. It can be said that the ends sought in NEPA, explicitly stated in Section 102, are our national equivalent of and an analogue to the balance sought in the more recent global sustainable development declaration of the Brundtland Commission (World Commission on Environment and Development, 1987).

The NEPA went farther than the Brundtland Commission did by requiring the assessment of environmental impacts using an interdisciplinary approach in any planning and decision making with an impact on the environment. In identifying and developing this interdisciplinary approach, NEPA makes clear the need to give appropriate consideration in decision making to environmental, economic, and technical considerations (42 U.S.C., Section 103).

The reference to NEPA here is important because it aptly reminds us of the need for interdisciplinary approaches and the balancing of environmental, economic, and societal goals whenever decisions are made regarding a product and its raw materials. NEPA also formalized the development of impact assessment methodologies and terminology that are reviewed here.

Risk Assessment and Analysis

The terminology of risk assessment can be particularly confusing if, as in our case, we move from ecosystem assessment to the assessment of individual organisms. Typically, a hazard is the source of a harm. The likelihood of harm from exposure to or occurrence of a hazard makes it a risk. Many consider risk analysis to be the whole process and risk assessment to be the portion that assigns magnitudes and probabilities to the adverse effects of human activities or natural catastrophes (Cohrssen and Covello, 1989). In the regulations implementing NEPA, "effects" are equated with "impacts" (Code of Federal Regulations). Thus, impact assessment defines the magnitude and probability of the effects of human actions on resources and the environment.

The implicit recognition of uncertainty and the probability associated with any risk are central to impact assessment and environmental decision making. They make it possible to obtain a balance of competing interests and to set priorities. Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA); Toxic Substances Control Act (TSCA); Federal Food Drug and Cosmetic Act (FFDCA); and Occupational Safety and Health Administration (OSHA); for example, in similar fashion address the issue of unreasonable risk that implies the notion of the magnitude and probability of an impact. Assessment of the risk of given impacts is achieved by focusing on endpoints.

Endpoints

Any assessment must define endpoints. The endpoint in the expression of the value to be assessed or protected. Some assessments—for example, one that examines the health effects using of a specific product—use specific, discernible, and available endpoints. We could be talking about specific chemicals and recognized endpoints in the area of human health. However, the assessment of impacts and effects on ecosystems—those that affect resource use, for example—is different because the endpoints are less evident and harder to measure, and the values to be protected are numerous and conflicting. There are no recognized models for integrating the multitude of variables that influence the biologic organizational hierarchy that exists in an ecosystem.

Endpoints are important in the description of the wood product system because they vary according to the different elements of the overall product system. They also pose definitional challenges. Endpoints must be descriptive of the values or attributes to be protected or that are at risk, and they must be able to define the values or attributes in operational terms. If not measurable or estimated, the assessment is incomplete (Sutter, 1993).

It is easier to define the values we want to protect than it is to measure or estimate them. In the area of human health, the effects of radiation, food contamination, and exposure to airborne chemicals, among others, are easier to relate to endpoints. In contrast, in ecosystem assessment, the selection of endpoints and their operational terms is more difficult. Values expand over a broad range of aesthetic, social, economic, and environmental considerations on which clear agreement must first be obtained. Different endpoints apply for each stage in the product life cycle. The convenience of using a product system model to explain impact assessment and endpoints is discussed in the next section.

PRODUCT SYSTEM

The model of a product system allows us to focus on the product, its raw materials, and its societal uses and consequences. The model consists of three primary systems: the ecosystem, the product system itself, and the social system. The product system interacts and links itself with the ecosystem and the social system. Figure 9-1 shows how the product system is connected to and interacts with the other two primary systems (Galeano, 1996a).

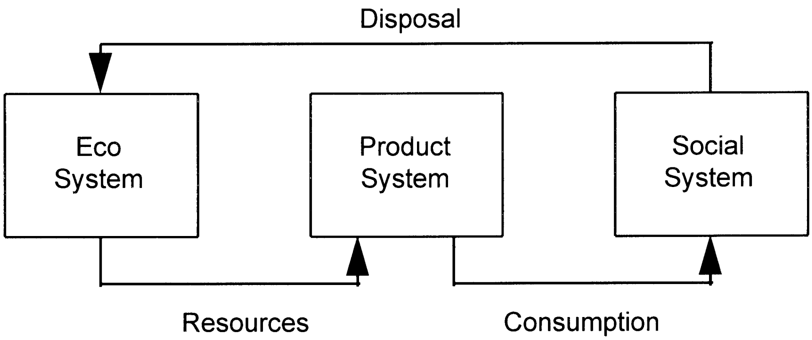

FIGURE 9-1 Model for the product system.

The ecosystem supplies the abiotic and biotic resources. In our case, wood is the primary biotic raw material for wood products, including paper products. The industrial use of wood results in the supply and distribution of products to the third system, the societal system. The societal system creates the demand for the products, which it uses and discards in different ways. Releases from the product and societal systems go back to the ecosystem, affecting it in different ways, along with the effects resulting from the processes and operations involved in the supply of raw materials.

Different approaches and methods are required for the purposes of environmental impact assessment and decision making for each system. The tools available for assessment of each system are in different stages of development. Impact assessment methods are mostly site specific in concept and application. Only one, life-cycle assessment, attempts to quantify relevant environmental aspects along the whole chain of the product system. The simple model of the product system advanced here will better permit a clear explanation of the different assessment methods and endpoints and their relationship with the decision-making areas we are focusing on.

MAJOR IMPACT ASSESSMENT APPROACHES

There are many approaches to impact assessment, and there are quite a number of terms, some of which overlap when used to describe similar approaches. A simplification is used here. Table 9-1 is a summary of the breadth and depth of impact assessment methods and applicability. It illustrates, for each element of the product system model, the applicable major assessment methods, as well as the endpoints and distinguishing characteristics from the other elements of the model.

There are four major assessment approaches that deserve a brief description here. These approaches are either the ones most applicable or the ones subject to controversy and discussion.

TABLE 9-1 Assessment methods for elements in the product system model

Ecosystem	Product system	Social system
Assessment method		
Environmental impact assessment	Life-cycle analysis, life-cycle inventory	Human health risk assessment
Ecological risk assessment	Extended product stewardship	Toxicology
Ecology	Product stewardship	Epidemiology
Aquatic toxicology	Risk assessment—human health	
Environmental toxicology	Site environmental impact assessment	
Endpoint		
Changes in species diversity	Source reduction	Carcinogenecity
Changes in community structure	Pollution prevention	Genotoxicity
Physical destruction	Food packaging safety	Aesthetic values
Wildlife preservation, endangered species	Waste minimization	Recreational values
Forest management certification	Energy conservation	Property damage

• An environmental impact assessment (EIA) as demanded by NEPA, includes effects or impacts on ecology (natural resources, components, structures of ecosystems) and human health and on economic, social, and aesthetic considerations. It is a comprehensive concept that requires the use of interdisciplinary approaches. Although deterministic models are used in EIAs, stochastic models that provide an estimate of uncertainty also are acceptable. EIA is not precisely a methodology, but a term developed by NEPA to address the need for assessing impacts by means of already established or new assessment methodologies.

• Human health risk assessment. Although NEPA resulted in new fields of expertise, such as ecological risk assessment, other statutes and interests have formalized assessment in the areas of human health. In 1983, the National Academy of Sciences recommended that government agencies publish risk assessment guidelines (National Research Council, 1983). The Environmental Protection Agency responded in 1986 with five guidelines covering areas of human health. It is important to realize that here we refer primarily to chemicals that impact on recognized endpoints, a classic toxicologic task.

From a toxicological point of view, the Environmental Protection Agency (1986) defines human health risk assessment in terms of four components: hazard identification, dose– response assessment, exposure assessment, and risk characterization. It must be understood that this type of assessment is mostly concerned with discrete chemical or physical stressors on individuals and populations.

• Ecological risk assessment. The ecosystem and organisms within it are different from human in terms of exposure pathways, metabolic rates, energy flows, and other characteristics. This is why there is a need to address these areas under a more specific and applied methodology, ecological risk assessment, in which the degree of complexity and difficulty in obtaining the proper information for a risk assessment is proportional to the rank or level of the organization under consideration (an ecosystem is the highest, an individual is the lowest).

Closely connected to ecological risk assessment is *ecology* itself. The assessment of human effects on the ecosystem must address the impacts and variations that occur even in the absence of human intervention. Ecology has been evolving from a descriptive discipline to one more interested in describing the mechanisms that explain interactions. This transition to an experimental science still needs improvement. Price et al. (1985) call for a more consistent application of the scientific method and for the appreciation for negative data in experimental ecology.

• Life-cycle analysis is a more recent attempt to assess impact in a whole product system. The methodology was designed to incorporate several phases. The phase in which an inventory of data is gathered uses mass loading expressed in terms of functional units defined for the specific product system under study. Impact assessment has not yet been fully developed, but it attempts to explain the results of the inventory phase by means of stressors—conditions that could lead to impairment of human health or the environment or to resource damage. The Society of Environmental Toxicology and Chemistry (SETAC) advances five methods for assessing stressors for *potential* harm to human and ecological health:

1. loading assessment;
2. impact equivalency assessment;
3. loading factoring, toxicity, persistence, severity;
4. generic exposure–effect assessment; and
5. site-specific risk assessment.

Level 5 will bring us back to more traditional, already developed assessment approaches. SETAC is placing emphasis on developing an acceptable methodology around Level 4. This would lead, at best, to one more of the already existing “ranking” or “scoring” approaches, which perhaps could be used as screening tools for future assessment studies (SETAC, 1993). Still, the lack of exposure data and spatial differentiation of impacts would make unrealistic any application to the forest product system.

It is important to recognize that SETAC has admitted that life-cycle analyses cannot be used to predict loss of biodiversity (SETAC, 1993), nor would the stressors indicate a cause-and-effect relationship. A more recent study report on research needs in life-cycle analysis for the European Union (Groupe des Sages, 1995) states that spatial differentiation of impacts is a critical issue specifically as it relates to equivalence factors. Equivalence factors were thought initially appropriate for life-cycle analysis. Spatial differentiation of equivalent factors is another area not yet developed but necessary for use in the attempt to assess forest systems that can encompass various ecosystems. Finally, the nonthreshold assumption, well embedded in life-cycle analysis impact assessment, uses the circular reasoning that, although impacts cannot be ascribed to a product or to parts of the product system, the loadings and consumption associated with the system could contribute to impacts and thus must be considered.

ECOSYSTEM

Of the three elements of our product system model, the ecosystem element requires the most attention. It is undeniable that concerns and interests about how forests are managed are very much present and reflected in public opinion. It is important for all of us to avoid unfounded demands or overexpectations on assessment methods. Decisions made with erroneous inputs or based on exaggerated "cautionary principles" are bound to be inefficient and contrary to the concept of sustainable development. The above discussion cites the reasons for eliminating life-cycle analyses for purposes of ecosystem environmental impact assessment.

Most of the comments made here about ecosystems are applicable to the use of other resources, including the use of wood as a raw material. The needed research in these areas would be more efficient and effective if conducted first at the level of generic resource use. This chapter stresses resources and human and ecological values. Nevertheless, forests are valuable for many reasons, such as for recreation, for economic return, for aesthetics, and for their social and cultural importance. Assessments for the purposes of decision making are thus never made on the basis of achieving a single environmental assessment result. As mentioned earlier, the ecosystem assessment presents peculiarities of its own, one of which—the use of organizational levels—deserves special attention.

Hierarchy of Organizational Levels

When discussing ecosystems, we should keep in mind that the levels of organization of the ecosystem are important. This is a characteristic that distinguishes the ecosystem element from other elements of our product system. The organizational levels are as follows:

- individual organisms;
- populations of organisms;
- communities, groups of populations;
- ecosystems, communities in a given environment; and
- regions, groups of ecosystems.

The hierarchy is important for impact assessment in more than one sense. First, it introduces a major difference for toxicologic approaches in individual organisms—the classic situation in human health assessment. In nature, individual welfare is subordinated to higher interests. In addition, the endpoints that can be defined, and even measured, at any level of the hierarchy, are nevertheless of different importance at each level. This peculiarity creates problems for their practical use in assessment or measurement.

Furthermore, the cost and complexity of testing and monitoring at higher levels of the organization, usually populations or larger groups, increases while the precision and accuracy of the data decrease. Finally, temporal and spatial scales are more critical in ecosystems, such as forests, both for stressors and for endpoints, than they are in individual organisms.

At a glance, this description of assessment characteristics of ecosystems should indicate the problems in trying to apply a generalized and comprehensive impact assessment methodology that would provide a clear direction for decision making. Life-cycle analysis is not the tool to assess natural resources or land uses because of its lack of spatial differentiation of impacts and time functions. As indicated earlier, experts developed the concept of stressors and specific levels of assessment methods for alternative forest assessments. To implement Level 5, we, of course, do not need to talk so much about life-cycle impact assessment but instead we should evaluate other assessment methodologies, such as those described in Table 9-1.

Endpoints And Their Measurement

The importance of identifying proper endpoints and their measurement is clear. All use of resources, biotic or abiotic, entails an interaction with an ecosystem or region (group of ecosystems). Let's consider the following as examples of ecosystem endpoints:

- physical destruction or major alteration,
- changes in ecological community structure,
- changes in biodiversity,
- endangered species selection and protection plan effectiveness, and
- quantitative sustainability of renewable and nonrenewable resources.

It is easier to list these endpoints than it is to reach consensus on their definition and measurement. For that reason, in the area of ecosystem impact assessment there is a dire need to conduct more applied research.

BETTER ASSESSMENT OF ECOSYSTEMS

Georgia-Pacific's voluntary efforts on ecosystem protection have as a defined endpoint endangered species protection. This could give the impression that this is a clearly definable and measurable endpoint. That is not the case. The process for listing endangered species in our country is complicated—driven by politics, observation, and some science.

When considering the issue of sustainability of resources as an endpoint, the complexity increases, perhaps exponentially. Is sustainability a value to be protected or a measurement itself of other values? Sustainability is not an inherent characteristic or property of a resource but the result of a management or policy decision about a resource.

In the case of biotic resources, with their inherent and scientifically demonstrated ability to reproduce the consequences of a management or policy decision are reversible. Can the reversibility of given effects make their methodologic assessment inappropriate for decision making? How to treat these differences in defining endpoints should be the subject of comprehensive research for all resource use. Such research would indicate the differences between definable endpoints for biotic and abiotic resources.

Measurement

Even in the measurement of timber there are different approaches to estimating the amount of merchantable wood on a tract of land or region. The California Area Timber Survey (CATS), the Timber Inventory Growth and Harvest (TIGH) and the Forest Inventory Assessment (FIA) projections are examples of some of these approaches, and they often result in different estimates of timber amounts for the same tract land (Wildland Resources Center, 1993). Resolution of differences is important, but more critical is the decision about their use in estimating long-term, regional system yields. The merchantable wood measurement methods are not balanced for harvest and growth measurements. Harvest and mortality estimates do not establish any preconceived threshold that excludes wood volumes from measurements. Instead, the growth measurement excludes growth smaller than breast height diameters of six or eight inches.

Biodiversity Conservation

Moving into biodiversity conservation as an ecosystem endpoint could also prove fraught with imponderables. Before experts lay out conservation plans, there is a need to know what to conserve and why. At a given time in the decision-making process, biodiversity conservation areas might need to be defined as a proportion of the country's available land area. Today, around 10.5 percent of the continental United States land area is, to some extent, protected. This proportion is one of the largest for any country in the world. Nevertheless, in these areas biodiversity conservation plans are not fully developed, and where plans exist, there are not suitable ways to have them analyzed. It seems that these areas should be ideal for research and analysis before demanding cross-country demonstration of biodiversity.

It is apparent that human intervention creates a reduction in diversity index for specific situations, depending on the severity of such intervention. The perception is that a higher diversity index means a greater number of species and that this is good in all circumstances. Nevertheless, the index create a mathematical trap. If the number of species is low but evenly distributed, the diversity index will show high. In addition, the sampling or testing methods can influence results. The notion that low diversity results only from human intervention is not true in all cases. Remmert (1980) cites the example of central European beech forests as the result of logging. This is not to say that biodiversity is not important, but that it needs to be defined for a given ecosystem or region, at a given time. Miner and Lucier (1993) have discussed these complexities.

Measurements Of Biodiversity Protection Plans

In terms of measurement, biodiversity offers technical and economic challenges that cannot be ignored. The most recent effort to provide a surrogate for biodiversity measurements is the gap analysis system (Scott et al., 1993). It is intended to identify gaps in the protection of biodiversity in management areas. It is no panacea, and its limitations have been advanced candidly by it proponents. However, it could be expanded to other areas or used as a productive mechanism to anticipate areas needing such management protection.

MANUFACTURING, USE, AND DISPOSAL SYSTEMS

In the processing of raw materials, resources are consumed and environmental loadings—in the form of emissions, releases, or both—take place. Both in the paper and in the wood product system, chemicals are released into the environment at different stages of the product system. Impacts could occur in ecosystems other than forests, such as woodlands, desert areas, or in regions composed of different ecosystems. For those cases, the earlier discussion on ecosystems is applicable.

Product Stewardship

We have spent considerable time on the issue of ecosystem impact assessment as applied to decision making because it is by far the most complex impact assessment for purposes of decision making. By definition, product stewardship involves understanding the resources consumed and the environmental, safety, and health impacts of the products we manufacture, to ensure these impacts are controlled or minimized (Galeano, 1995).

As depicted in Figure 9-2, product stewardship relies on two assessment tools: risk assessment and life-cycle analysis. The most traditional human health risk assessment techniques are applicable either at the manufacturing site or during distribution, use, and disposal of the product. It is possible to say that regardless of the debate about these assessment tools, they provide input that is to a large degree adequate for decision making.

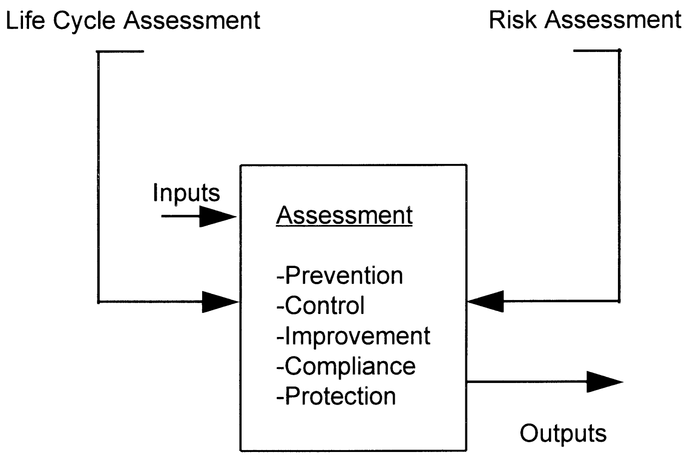

FIGURE 9-2 Product stewardship.

Extended Product Responsibility

The concept of extended product responsibility (EPR) considers the entire life cycle of a product, from design to disposal, to identify opportunities for resource conservation and pollution prevention. EPR is based on the principle of shared responsibility among suppliers, manufacturers, users, disposers, and policy-making entities (legislatures, regulatory agencies). The greater opportunity for stewardship rests in the links of the product chain with the greater ability to influence the life-cycle impact of the specific product system. In the upcoming report of the president's Commission on Sustainable Development, EPR is the second policy recommendation of the commission. This is the result of lengthy and careful examination of new concepts and approaches in policy making and with the participation of a wide representation of interest groups and government representatives (Galeano et al., 1995).

This new concept is based on the search for more "ecoefficient" approaches, and it requires impact assessment methodologies to help in decision making. Figure 9-3, which depicts the position of EPR in a structure for sustainable development, illustrates the need for assessment tools in reaching decisions. All of the above discussion on methodologies and the balancing of competing factors is applicable to EPR in a more complex fashion.

Life-Cycle Inventory Analysis

Life-cycle inventory analysis is a useful portion of the analysis of a product system as presented in Table 9-1. The inventory phase of life-cycle analysis methodology provides information that, with proper qualifiers and interpretation, will be useful for manufacturers and business in general. Lately, for forest prod-

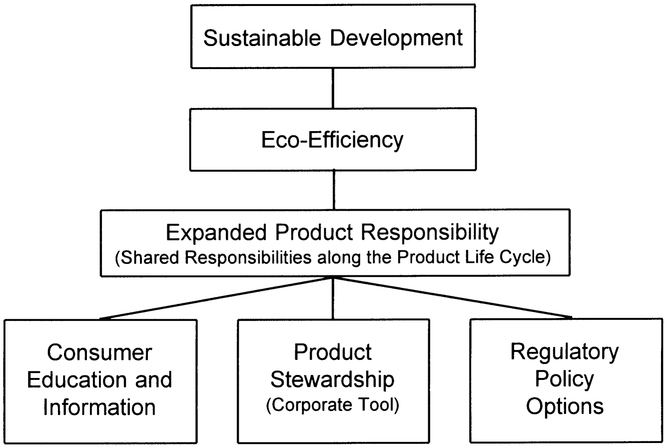

FIGURE 9-3 Expanded product responsibility within the sustainable development structure.

ucts, the inventory methodology has been enhanced to better reflect characteristics and operational features particular to our products and operations (Galeano, 1996b). Table 9-2 lists the six basic enhancements, which make possible a more credible and reasonable interpretation of results from the inventory phase. They also provide the conceptual framework under which system boundaries are drawn in a manner that justifies the proper expression of important forest products characteristics and operational factors. For example, extending the boundaries of the product system to the seedling allows for interpretations about CO_2 sequestration, renewability of the raw material, renewability of the biomass energy, and allocations for coproducts and recycling.

In this sense, the life-cycle inventory is about a trade-off. In the context of product stewardship, it is a tool that helps in decision making. Source reduction, pollution prevention, waste minimization, and resource conservation could benefit from proper life-cycle inventory studies. Beyond that, efforts to use the in-

TABLE 9-2 Enhancements to the life-cycle inventory

- Proper product system boundaries to justify
  - Renewability of the material
  - Renewable biomass energy
  - Carbon dioxide sequestration
  - Solid-waste management practices
- Allocation procedures
- Interpretation of results

ventory as a tool to establish a product's overall environmental superiority or preferential purchases have not been successful. The methodology can assess, in a comparison, specific parameters and reach qualified comparative assertions between products.

CONCLUSIONS

The above analysis permits several conclusions:

The implications of impact assessment for decision making about wood as a raw material and about its products can be better ascertained by evaluating a model of the entire product system.

No single method of impact assessment alone can provide the input for final decision making. Rather, balancing environmental, economic, technical, and societal values will provide the best sustainable development decision.

Environmental impact assessment approaches are applicable to different elements of the product system model. Not all assessment approaches are applicable to the entire system. The different endpoints and biologic organizational levels in each system impede the use of a one-size-fits-all assessment methodology.

Life-cycle analysis, in its inventory phase, is a tool with potential for analysis of trade-offs and hypothetical situations. The impact assessment phase, even if an appropriate methodology is developed, will not be of use in evaluation of ecosystems.

For wood products, specific enhancements in the life-cycle inventory methodology are in development to properly reflect characteristics of biotic resources. Only in this manner will life-cycle inventories be useful for wood products assessment in product stewardship and extended product stewardship situations.

Impact assessment approaches applicable to ecosystems are eminently site specific and eventually consist of different subelements or approaches. Their input into decision making is piecemeal and still subject to improvement. No single risk assessment approach can cover all of the major recognized endpoints.

We have advanced examples of areas for future research to improve evaluation of ecosystems and in particular of the forest. They are given to focus attention on their need.

Certification of forest management schemes should not factor in requirements that involve assessment endpoints for which the methodology and measurements have not yet been developed.

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CHAPTER 10

Policies Today and for the Future

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The focus of discussion to this point has been on process and measurement. My assignment is policy. Specifically, my assignment is to find the largest potential environmental policy impact and, to do this, I think I should begin with the problem rather than with the process.

We all agree that the United States, and the world, will continue to use wood as a raw material and that, wherever we harvest this raw material, we will have an impact on the forest environment. The problems are how to control the environmental impact and how to leave us with a sustainable natural system. There are no easy solutions because any adjustment in the environmental impact will have its own consequences: on production costs and consumer expenditures, on substitute materials that have their own environmental sources, and directly on the forest environment itself. Therefore, our real problem is not just to control the environmental impact of industrial wood production, but to control it relative to the financial, political, and environmental costs of the control activity.

This chapter has three underlying themes: how to measure environmental impact, what the government role should be in any environmental solution, and what the impact would be of any potential solution on the international competitiveness of the wood products industries. I am going to address the impact measurement topic, propose my idea of the most environmentally effective policy, and then examine the role of government, and international competitiveness, in that order.

A good opportunity emerges from this organization of the problem. This opportunity is technological progress in the wood-processing industries. I am going to try to convince you that technological progress in these industries is something that clearly benefits consumers, industry, and especially the environment. It is also something the United States is good at. I think the evidence is strong that technological progress yields greater environmental gains than most direct, on-the-ground environmental regulations, and it is probably less expensive and more generally palatable to a breadth of constituencies. In terms of the environmental interests expressed by many, it saves wood energy. The problem is how to find the policy structure that encourages it. Let's begin with the broadest general definition of our problem, measurement of the environmental impact, and then consider the policy recommendation.

MEASURING ENVIRONMENTAL IMPACT

Our first task is to find a general measure of forest-based environmental impact. Many specific environmental features of forests require protection, and many analytical techniques provide the means to measure our successes and our failures at protecting forested environments. We can find useful physical indicators of protection for almost any special environmental feature we desire. For example, we have no difficulty identifying, counting, or establishing indicators of the secure protection of uniquely scenic vistas or the habitats of endangered species. The difficulty arises when we try to make policy decisions across competing environmental features and try to set priorities among them. For this task, we need a more general measure.

Life-cycle analysis, as discussed in this volume, is one alternative. Economists have another system of value and several specialized techniques for assessing nonmarket values. Neither life-cycle analysis, economics, or any other comprehensive assessment technique receives universal approval—and I am not going to argue for my favorite technique. This is one occasion when I think argument is unnecessary.

I will argue that, in our case, industrial forestry, a simple area measure of land actively used for timber management and harvest, is sufficient and that, generally speaking, the smaller the total land area in commercial wood production the more environmentally friendly the forest practice. Of course, this is a general rule. It does not deny the critical importance of specialized environmental standards for special cases involving specific forest land areas.

Our usual focus in forestry—for life-cycle analysis, economics, or whatever—is on a fixed and constant area of forest land: an acre, a timberstand, a watershed, a small ownership. We plan timber harvests for fixed areas of forest land, and we regulate compliance with acceptable forest practices on similar well-defined land units. This focus is appropriate for small landowners with fixed areas for their land use activities. It is inappropriate for large landowners, for industrial consumers of wood as a raw material, and for environmental policy analysis.

Forestry is an extensive land use, and most of the important trade-offs in forestry are between acres or timberstands or watersheds rather than between alternative management practices on one acre or one timberstand. I cannot deny that stricter environmental controls on one acre will alter timber management and harvest practice on that acre. Stricter controls do tend to decrease harvests (and raise timber management costs) per acre per year, but they also tend to push some timber harvests to new land areas that would not have been harvested as soon or as frequently. Therefore, even where environmental control is placed on a specific land area, its impact rapidly extends to new land areas.

Consider three general examples: Silvicultural regulations in British Columbia decrease harvests by 12–17 percent (Price Waterhouse, 1995). We know that most of these harvests will be replaced with harvests from someplace else, perhaps inland Canada, perhaps Oregon or Washington, perhaps Siberia, perhaps the tropics. Each of these alternative regions has its own environmental disadvantages. For a second example, public forest managers in the United States, in the presence of increasing environmental protection, attempt to maintain their national "allowable cut" targets. To accomplish this, they must replace harvest reductions in newly protected areas of national forests with additional harvests from other national forest lands. The large wood-processing companies provide the third example. Their heaviest capital investments are in their mills. Closing or moving these mills is expensive. Therefore, in the presence of more stringent rules for environmental protection, many of them moderate their forest management and timber harvests on some acres, harvesting less and improving environmental protection. But they compensate by extending the areas of their timber purchases to lands and landowners who would not have sold timber or would not have sold as much timber as often.

We can anticipate that the new areas of extended harvesting are less attractive. They are less commercially viable and more environmentally risky. They have steeper slopes and shallower soils, or they occur on sites with poorer drainage. If they had been commercially and environmentally better sites, then they would have been scheduled for earlier harvests. Therefore, direct environmental controls improve the environment on currently managed forest land, but they also cause us to expand the harvest area, and thereby to depreciate the environment on other, usually more fragile, lands that would not have been harvested in the absence of the environmental protection.

I do not have a good quantitative estimate for the trade-off between environmental improvement on one acre and harvest extension and environmental deterioration on another. I suspect that the land areas involved are large and the impacts are significant. One bit of suggestive evidence of the potential area affected comes from the best available long-term projection of world timber supply. Sedjo and Lyons (1990) project that one-half of the world's industrial wood fiber through the year 2050 will originate from marginal lands or frontier forests. This means that the world opportunity is great for using our increasing environmental concerns to shift our timber harvests to ever more marginal forest lands, and it means that we take large advantage of this opportunity now and we will continue to do so until at least 2050.

This all suggests that one useful comprehensive metric for assessing industrial impacts on the forest environment is acres of land used. The more acres, the greater the environmental impact and, conversely, anything that decreases total forest acreage in industrial use probably improves general environmental quality.

REDUCING LAND USE AND ENVIRONMENTAL IMPACTS

The three possible approaches to decreasing the environmental impact of growing and harvesting wood are increasing on-site environmental protection or improving timber management and harvest practices, restricting timber management and harvest activities altogether from the most fragile sites, and decreasing the demand for industrial timberland. We discussed the first in the previous section and rejected it because it often expands the harvest area and, therefore, increases the environmental impact. The second approach is absolutely necessary to satisfy some important environmental values. This approach is identified with more than 24 million acres that are unavailable for the land base of industrial timber activities in the United States. Undoubtedly, the political debate over these acres and additional forest land set-asides will continue. I will not deny the controversial issues of the second approach, but I will concentrate on the third.

There are two methods for decreasing the demand for industrial timberland: intensifying timber production on some acres (produce more timber on less land) and decreasing the industrial demand for timber as a raw material (produce the same amount of lumber, furniture, or paper from a smaller volume of standing timber inventory).

Foresters are trained to focus on the first, and those of us with environmental interests naturally do the same. There can be no doubt that we possess the biologic production insight to sharply increase timber yields per acre. Our actual performance, however, has not been particularly good, perhaps because intensification is so expensive, especially compared with the alternative of harvesting those nearby marginal forests where mature natural timber stands ready for harvest.

Consider southern pine productivity, for example. The southern pine industry undoubtedly demonstrates the most rapid rate of technological advance for any segment of the U.S. timber-growing industry over the past half-century. It is well-known for the remarkable successes of its investments in tree improvement and its applications of intensive forest culture. Furthermore, the industry's continued willingness to invest in tree-growing research is evidence of its continued high expectations for some productivity increasing investments. Nevertheless, the overall rate of productivity increase in southern pine has been in the neighborhood of only 0.4–0.6 percent per acre annually, and this rate actually has been decreasing for the past 20 years (Hyde et al., 1992). The rate of productivity increase for southern hardwoods, and for softwoods from other regions of the United States or the world is probably smaller yet.

The overall rate of productivity increase in forestry itself will remain small because forestry continues to have a production opportunity to harvest from those less accessible acres whose importance I stressed earlier. This opportunity to harvest additional acres of natural material (whether old growth or volunteer forests on reconverted agricultural land) is a substitute for technological change in tree growing. It is a truly unique characteristic of forestry because neither agriculture, wood processing, nor manufacturing in general have similar unexploited and replenishing natural stocks of their basic inputs.

Compare the experience with improving silviculture productivity with the experience of productivity change at the mill. Risbrudt (1979), for example, found an average productivity increase for four SIC 24 (wood and wood products) and SIC 26 (paper and allied products) industries about 1.9 percent annually. Robinson (1975) found a 1.75 percent rate of annual technical change for the six SIC 24 classification (wood and wood product) industries. Greber and White (1982), Stier (1980), and Kendrick and Grossman (1980) each published similar results. Stier and Bengston (1992) reviewed these and 20 additional analyses. Their summary judgment is that technical change in the wood products industries is "wood neutral," which means its resource-saving impact on wood has been approximately the same as its general impact on all other inputs—or somewhere in the range of 1.75 to 1.90 percent annually. Loosely speaking, this means that technological change in the wood products industries annually saves more than three times, and perhaps more than five times, as much land as new silvicultural technologies save.

Consider just two specific innovations that make the point even more sharply: the powered back-up roller in a plywood mill and truss frame housing. The powered back-up roller applies even pressure on the raw log, thereby assuring smooth and continuous peeling for plywood. This single technology was designed, modified, and adopted by most plymills in the United States in the short span of 3 years. It is a small component in the full measure of wood-processing technical change, but it alone saves 17 percent on plymill wood consumption, or approximately one percent on all industrial wood consumption in the United States, and perhaps a comparable percentage of industrial forest land. Truss frames are built at central locations before shipment to various construction sites. Bulk production to standard specifications saves lumber in comparison with the alternative of individual beam, joist, and riser construction at each new housing site. The U.S. Forest Service calculated that truss frame construction annually saves a volume of wood greater than the programmed allowable harvests on all existing or proposed wilderness areas (Buckman and Wahlgren, 1989).

POLICY INCENTIVES AND THE GOVERNMENT

The losses to the environment due to timber management and harvest controls that spill over to harm other forested acres are probably significant, even if we cannot estimate with confidence the number of affected acres. The counteracting gains to the forest environment from technological improvement in wood processing are substantial and measurable with more confidence. The structure of the forest and wood products industries is a third reason to prefer technological change as the path to environmental improvement. Consider, first, industrial structure and the problem of enforcing on-the-ground environmental regulations, and then consider the incentives necessary to induce additional technological change.

Large firms have their own incentives to meet environmental quality standards. Some gain marketing advantages from setting high standards and informing the public of their performance. Some firms advertise their high environmental standards and, presumably, gain market share because of them. Moreover, those large concerns that do not have favorable environmental reputations are reluctant participants in the opposite—environmental noncompliance—because they cannot afford the negative publicity and the marketing consequences that go with it.

Smaller firms do not have such market profiles, and they cannot obtain marketing advantages even if they do maintain high environmental standards. Consider that we neither differentiate the products nor do we even know the names of many smaller forest or wood product producers. Furthermore, smaller firms often have older and less technologically advanced equipment, which usually means that it is more costly for them to make their operations environmentally friendly. I understand that most modern sawmills, for example, are scaled below the size of old-growth timber and that most of the mills that depend on old-growth timber in the Pacific Northwest (where old growth is such a controversial issue) are smaller and older.

This means that the potential for environmental gain in forestry is probably greater for enforcement programs that target smaller firms. But smaller firms—especially smaller forest landowners—are dispersed and less recognizable to enforcing agencies. Monitoring and enforcing standards on many smaller operations is more costly and, when effective, enforcement is more likely to drive smaller operators from the business. (Most of us would consider this an unsettling result.) We have some evidence for these points as well. Virginia's state forest practice act mandates reforestation after timber removal. The state forester's office conscientiously spends time and money enforcing the act, but there is no evidence that enforcement induces any increase in reforestation or in subsequent forest inventories (Boyd and Hyde, 1989). We also have the anecdotal observation that it is the small landowners, not the large industrial operations, who respond so vigorously to contemporary political concerns with landowner rights and environmental regulations.

If increased enforcement of environmental regulations in the forest would be expensive and if its results might not be very satisfactory, then could we obtain better results from increased investment in our alternative, industrial technology? The evidence here is much better.

Improving technologies are the results of investments in technology research. Therefore, the historic successes of investments in technology research should be good indicators of the promise of technological improvement. Public investments in technology research for the wood-processing industries have typically produced ex post average returns ranging from 15–500 percent annually and marginal returns often in excess of 15 percent (Hyde et al., 1992). This range of returns is exceedingly wide, but even its lower boundary is in excess of generally acceptable minima for private investments. It is also in excess of the cutoffs generally applied for public investments. It shows that wood-processing technology research generally has been a good use of public funds, and that expanding the research effort often would have been justified on market criteria alone. These calculations were made without any consideration of the value of forest-based environmental protection the investments induce. Adding this environmental value would only increase the estimated returns and improve the justification for expanding investments in technology research for the wood-processing industries. In sum, expansions in technology research would create savings in industrial wood consumption and, therefore, reductions in timber harvests and savings for the forest environment.

The public role in research is justified because new technologies reduce product prices. Consumers are the benefactors. The public captures the benefits of price decreases. The industry does not. Of course the industry benefits if the production-expanding effect of technical change is greater than the price-decreasing effect. Each of these cases occurs in different wood-processing industries. The price-decreasing effect is dominant in the sawmill industry, and the production-expanding effect is dominant in the pulp and paper industry. Consumers gain in each case. Producers also gain in pulp and paper. It is not surprising that industrial research expenditures are greater in the pulp and paper industry, and we would predict that sawmill research, with its relatively greater consumer benefits, justifies a relatively larger proportion of public financial participation. The sawmill industry is also a larger consumer of wood as a raw material. Therefore, new sawmill (or, more broadly speaking, lumber and wood products) technologies probably save more wood and more forest environment than would new pulp and paper technologies.

INTERNATIONAL COMPETITIVENESS

The final question concerns the effect of forest protection on international competitiveness. Environmental regulation increases on-site protection, and environmental compliance also will raise production costs (and extend timber removal to additional forest lands as well). It can only diminish the industry's international competitiveness. On the other hand, if green labeling and other environmental protection activities remain voluntary, then retailers will adopt the more costly labeling standards voluntarily when they perceive marketing advantages from this action. One place they might find a marketing advantage is in those particular international markets that currently demonstrate their environmental concerns by proposing green labeling.

Of course, this chapter suggests another alternative. Investments in technology research that decrease the industrial demand for wood can only improve our international competitiveness. New processing technologies decrease forest product prices, and lower prices will enable U.S. industry to penetrate new international markets. The machine manufacturers who supply the improved equipment for the new technologies also will penetrate new markets.

The relationship of wood products technology research to green labeling is not so clear. The environmental advantage of new processing technologies is real, but this argument will not be evident to every environmentally concerned wood product consumer. It is much easier to explain the direct and on-site environmental impact of improved silvicultural practices than it is to explain the often greater indirect environmental impact of new processing technologies. Making the environmental argument for new processing technologies could become a marketing challenge itself.

CONCLUSIONS

We have reviewed the measurement of policy impacts on the general forest environment, discussed environmental policies, and proposed that wood-saving technologies in the processing industries have a larger favorable environmental effect than do most policies that target the forest environment directly. I would suggest that a powerful coalition of environmentalists, consumers, the wood-processing industries, and wood technology equipment manufacturers would each obtain advantage from supporting publicly funded wood technology research. Furthermore, the sharply focused targets of wood technology research provide a real administrative advantage over the dispersed targets of regulation in forest environments. The decreased industrial impact on the forest environment will be an important result.

Finally, two particular characteristics of forestry must be foremost in the minds of each of us as we consider this recommendation to support technology research—or our own preferences for other policy actions affecting forest environments. Recall that we are not looking for any impact at all. Rather, we must look for the largest impact per expenditure of resources, including financial, political, and environmental resources. As we compare alternative policies, we must recognize, first, that environmental savings on a target forest site often expand the forestland base for the industrial production activity and environmental damage on new acres that otherwise would not have been harvested. Timber production costs are greater on the additional acres and the environmental impacts are riskier. Extending the industrial forest land base also raises the cost of environmental monitoring and enforcement. Second, the structures of the forestry and the wood and paper products industries are key determinants of environmental performance and the costs of environmental monitoring and enforcement. Large firms might be able to differentiate their products and obtain financial benefit from favorable environmental performance. Small firms cannot—and their environmental performance is less predictable. Furthermore, small and dispersed firms—especially small and dispersed forest landowners—are expensive to monitor, and their environmental compliance is irregular at best. These two land use and industrial structure characteristics will be major determinants of the relative effectiveness of whatever policy alternative is adopted.

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CHAPTER 11

Working Group Summary and Round Table Discussion

The final symposium session presents results of working group discussions that focus on weaknesses of current life-cycle methodologies, data needs, inherent biases of methodologies, and application considerations. In addition, round table panel participants provide insight on issues of forest products certification, development of international standards, and policy implications of life-cycle concepts.

WORKING GROUP DISCUSSION SUMMARY

Working Group Leaders:

David Briggs, *University of Washington*
Sergio F. Galeano, *Georgia-Pacific Corporation*
Dana Harmon, *Wood Reduction Clearinghouse*
William J. Nicholson, *Potlatch Corporation*
W. Ramsay Smith, *Louisiana Forest Products Laboratory*

Questions about life-cycle assessment methodology are posed to symposium participants, who work in small groups to identify answers. Working group leaders, appointed to document their working group discussion, provide summary reports. Questions and summarized responses from working groups are provided below.

1. What are data needs for assessing the environmental implications of using wood as a raw material?

There is a need to gather data on forest inventory and biomass in general, through coordinated efforts. Other needs include updating the data on a regular basis, improving methods of dissemination and transfer of data, and expanding the scope of data collected to include effects over time. A systematic approach for data collection could be developed and more complete data on solid wood, as opposed to pulp and paper, and natural versus planted forests, are needed for life-cycle analyses. A method to determine data relevance, or weighting of data, would be useful as it is incorporated into assessment methodologies. Within life-cycle analyses it also is important to have adequate and appropriate definitions of impacted areas. Impacts on areas outside the United States might be considered as assessment methodologies are developed and implemented. An update of the information contained in the 1976 National Research Council report, *Renewable Resources for Industrial Materials* is needed that focuses on environmental impacts and includes data for all materials substitutes (National Research Council, 1976).

Needed improvements to life-cycle methodology expand beyond enhanced data gathering and management. Methodologies must account for biologic aspects and impacts of forests, as well as spatial and temporal differentiation of impacts. Methods tend to focus on physical aspects of systems; economic and social aspects are not factored into the analyses. Questions remain about how to measure and incorporate values such as biodiversity and aesthetic satisfaction into environmental assessment methodologies. Boundaries of current life-cycle methodologies that begin with the harvested wood and end with the finished product could be broadened to include information on the tree in its environment and perhaps include assessments that consider post consumption impacts.

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2. How can modifications be made to life-cycle analysis methodologies to allow for unique local and market conditions?

Life-cycle methodologies could be modified to allow for differences in land types and management options including:

- natural generation,
- plantations,
- public lands and management objectives,
- private lands and management objectives, and
- tropical versus temperate landscapes.

While there are some common principles involved in life-cycle analysis methodologies that could be applied to many different situations, it is important to recognize that no single model fits all situations. For instance, various economic, regional, and societal needs could be accounted for in these analyses. Native American forested lands and lands devoted to special uses such as recreation are two examples of land types that might not be managed in the same manner as industrial forests; therefore, methodologies need to be flexible to handle various economic and social aspects of different land types. Ecosystem values and effects associated with timber, ores, oil extraction may involve greater differences in assessment methodologies than in subsequent product evaluations. There is also a need to look at how alternatives are objectively laid out for policy making and how comparisons among alternatives are conducted.

3. What are the biases that are inherent in developing life-cycle methodologies?

Life-cycle analysis and life-cycle inventory methodologies are only partially useful in the forest sector and therefore should be recognized for their biases and limitations. Current tools, such as life-cycle methodologies, are biased toward the North American and European style systems and cultures; they do not reflect the cultures and systems of developing countries. Life-cycle assessment methodologies and results tend to have a bias in favor of durable goods. Biases likely will be inherent in these analyses and therefore should be recognized as such and identified from the outset. Standards or guidelines are necessary to deal with these biases and these standards, as well as the methodologies, should have a scientific basis.

4. How should consumer, environmental, and industry interests be considered and factored into all aspects of assessment?

The process of environmental impact assessment needs to involve all stakeholders. Outreach programs could be developed to facilitate the opportunity for everyone to have input. A common set of values that is representative of all factions could be identified and applied to the life-cycle assessment process, while keeping the valuation process separate from the scientific data gathering process. As consumer, environmental, and industry interests are factored into assessments, there should be assurance that only scientific principles are used.

ROUND TABLE DISCUSSION

Round table discussion rapporteurs provide perspectives on key issues related to the application of life-cycle methodologies today and in the future. Aspects of certification, international standards, consumer acceptance, and questions about the adequacy of methodologies for use as regulatory tools and in policy making processes are addressed.

Seventh American Forest Congress Rapporteur's Perspective

WILLIAM BENTLEY
Salmon Brook Associates
Granby, Connecticut

I provide a few notes from what we learned at the Seventh American Forest Congress in February 1996. These comments might be useful and are presented in the context of our discussions during this symposium.

Clearly, most participants of this symposium do not have an in-depth understanding of the issues at hand. This lack of broad knowledge suggests that more work is needed, and the results must be clearly transmitted to a wide variety of critics concerned with America's forests.

The Seventh American Forest Congress met February 20–24, 1996 in Washington, D.C. Some 1500 participants, drawn from a wide variety of interests, experiences, and locales, considered 13 vision elements and 60 principles to guide America toward its vision for forests. Over 90 percent were in agreement on one element, over 80 percent were in agreement with 5 elements, over 70 percent were in agreement with 8 elements, and over 50 percent were in agreement with 12 elements.

A similar review of the 60 principles yielded the following results: 80 percent or more agreed on 6 principles, over 70 percent agreed on 11 principles, and over 50 percent agreed on 29 principles.

These levels of agreement are remarkable, as is the breadth of the vision elements and the principles; they clearly demonstrate respect and strong support for:

- diverse ownership and user values,
- private ownership rights and responsibilities,
- rule of law,
- ideal of open dialogue and political process,
- science-based information and strong research systems with ties to all stakeholders, and
- long-term learning and effective education about forests.

Interestingly enough, the one vision element that stimulated an ambiguous response dealt with reducing consumer demand and using recycling (and did not include increased productivity). Some of the ambiguous response was due to omitted words and ideas, but more importantly, the ambiguity centered around complexity and lack of information and understanding.

The results of the Forest Congress reinforce the concerns presented during this National Research Council meeting. The process of addressing these concerns about better understanding environmental effects of wood used as a raw material, will lead to much higher levels of agreement and to new principles. The answers also will help link forests and forest-based values to broader social and environmental concerns of Americans.

Certification and Standards
Rapporteur's Perspective

FREDERICK W. CUBBAGE
North Carolina State University

This volume concerns certification of forest products, the ISO 14000 standards, life-cycle analysis, and related concepts. The use of wood as a raw material has energy and environmental implications, and many advocates note that wood is an energy efficient, renewable natural resource commodity that has very little impact on the environment and is in fact often beneficial. Proponents of other nonrenewable resources advocate the benefits of other commodities, and suggest that alternative materials have less impact on the environment, especially on a broad-area basis. Critics of intensive forestry also tend to believe that forest practices can be harmful and should be monitored. These diverse concepts come together in the proposals for life-cycle analyses and the environmental standards of the International Organization for Standardization (ISO), which would measure the entire environmental and energy impacts of the use of raw materials for construction or other development purposes.

This chapter contains brief reactions to the proposals presented elsewhere in this volume. The comments in this section are provided from the perspective of a forestry professor and department head with a background in forest policy and economics, a researcher in nonindustrial private forestry, and a southern nonindustrial private forest landowner. Comments from industry and trade group representatives are contained in the other two sections of this chapter.

In general, my comments are intended to be critical, but constructive, suggestions about the merits of the volume's proposals. I do not personally ascribe to all the beliefs I recapitulate here, but I do believe that as an observer of southern forestry and politics, some potential problems bear mentioning.

Regulatory Concerns

The first question I address here has to do with whether the proposed implementation of certification, standards, and life-cycle analyses would cause concern that they might become regulatory. Yes. There is great concern in the South that such initiatives will become regulations. For example, best management practices in several states started as voluntary approaches and later became required. Requirements for certified wood might easily follow voluntary provision of certification.

The President's Commission on Environmental Quality (1993) listed several of the concerns about efforts and regulations to improve biodiversity, which remain relevant to certification efforts. Guidelines (or regulations) might limit or halt profitable land uses, or at least increase costs; reduce our ability to meet the nation's needs for commodity goods and services; pose difficulty for measuring results or direct benefits; lead to conflicts among regulatory approaches; or "elevate" the baseline level of regulation or "guidance," so that stricter measures would be required later.

The recent and deep-seated private property rights movement also might hinder acceptance of the certification–standards approaches. Many landowners in the South oppose any perceived infringements on their property rights. Forest landowner and farm interest groups stridently oppose most regulations, or guidelines that could become regulations. Conservative legislators and Congress members would gleefully oppose this further involvement of big government, and even big business (paper companies and others) are subject to some criticism these days. Standards will be seen as one more extension of the camel's nose in the property rights tent, and they will be opposed strongly.

Administrative implementation of voluntary standards will be extremely difficult and expensive as well. For example, one proposal suggests that certification require a management plan, site inspections by a certifier, and a landowner interview. Studies we performed in Georgia suggest that less than half of the nonindustrial private forest (NIPF) land area in the South receives any formal forestry advice before harvesting (Hodges, 1988); surely a much lower percentage of landowners receive advice. Probably less than 10 percent of the NIPF landowners or area have formal management plans (Hodges and Cubbage, 1990), and only a few states perform any formal site inspections. There are about 5 million landowners in the South, and 9.9 million in the nation (Moulton and Birch, 1995). Certification and inspection of all these sites before harvest is far too difficult to achieve, even with all the industry and state and consulting programs. My employer, North Carolina State University, would be pleased to find this much more work for our forestry school graduates. NIPF landowners, however, might not be so pleased about the red tape and expense required.

Methodological Adequacy

The next question to consider is whether the methods described for use in certification, life-cycle analyses, or standards are adequate. Assume that this refers to their environmental adequacy for forest management, based on scientific knowledge. The short answer is no. The methods that seem to be used to date can be pretty sophisticated, but their mathematical elegance far outstrips their scientific or practical bases. It looks as though few, if any, of these approaches have been through scientific review and have been published, either as individual studies or as integrated rating and scoring systems. Few of the approaches look as though they would ever be accepted for publication in scientific journals, and some do not even seem like more than educated guesses based on gray literature and pseudoscience. The weakness of these approaches shows promise for uniting landowners and scientists for the first time in forestry—in opposition to their implementation. The scientists surely would like to increase the science behind these approaches, however, and probably would be willing to perform applied research if reasonable funding were provided.

Consumer and Industry Acceptance

The concept of wood or forest environmental certification clearly has potential for acceptance by consumers and by the forest industry. Citizens consistently express their beliefs that we should do more to protect the environment, and "green" products are generally accepted as desirable. The degree to which this general belief can be translated into widespread acceptance of requirements for green labeling, and whether American consumers will actually pay more, is moot. Anecdotal information from the United States and Europe suggests that standards will be received gladly. On the other hand, there is some indication that there is little willingness, at least in the United States, to pay more for labeled products. Furthermore, many consumers are too busy or indifferent to spend a lot of time, let alone a lot of money, to figure out and preferentially purchase "green" products.

Green labeling and certification also raise consumer equity considerations. These efforts will probably raise prices for consumer products, which will be differentially borne by poor people who spend more of their disposable income on shelter and paper products. As mentioned, NIPF landowners, who are producers of wood and environmental benefits, as well as consumers of certification services, might not accept these guidelines or requirements graciously.

The forest products industry also could view certification with ambivalence. Their costs might increase and profits decrease because of certification programs, but if the costs can be passed on to consumers, or if certification allows them to gain market share in the United States or abroad, their objections might dwindle. If the guidelines or standards affect trade and become nontariff barriers to wood sales, neither industry nor NIPF owners will be pleased. The potential of the standards to discriminate against the use of fast-grown plantation wood, which is becoming more profitable and popular in all of the Americas, is undesirable to most U.S. forest landowners. Large increases in the management costs also are not desired.

There could be some merits of environmental certification and standards for NIPF landowners and for the forest industry, other than just market share concerns. The President's Commission on Environmental Quality (1993) addresses these issues. First of all, employees and forest landowners do want to protect the environment and act as good stewards of their forests. Good feelings and goodwill can result from positive environmental action. This can extend to good neighbor and community relations, and to good public relations as well. Participation in certification programs can help build trust with regulators and consumers. In some cases, good stewardship practices might lead to operating cost savings if they prompt better means of performing actions or help protect long-run site productivity.

The degree of exhortation or coercion will also influence the view of producers and consumers in certification programs. Voluntary or exhortatory programs are more likely to be well received than are coercive or regulatory programs. Providing producers the option to participate will make their responses more attuned to market benefits and less of a command-and-control demand. Given the rather shallow scientific bases and potential for biases in current certification efforts, a voluntary approach certainly seems preferable. This could be likened to the opportunity to buy organic food. Environmentally certified wood will gain a share of the market based on its merits, but not all consumers will be forced to pay more for the implicit benefits, which will vary among buyers.

Market Issues

The various types of forest certification and standards for environmental protection can be viewed as an extension of market economics, or an interference in market economics, depending on their application and the degree of coercion applied. A single-sector (forestry) standard—such as the International Organization for Standardization's document—would obviously tend to discriminate in the market against forestry and wood products to the benefit of other renewable or nonrenewable resources. Forestry criteria that favor or mandate natural stand management and longer rotations excessively will penalize market responses to wood scarcity and thus cause forest landowners to lose profits.

Certification programs should involve consumers, environmentalists, and forest landowners to avoid biases against market resource allocation. To date, all of the forest certification standards and approaches ignore economic factors such as costs, prices, profits, or employment. And the assessment of community benefits proposed by some certification programs has considerable potential for arbitrary measurement and application. The biocentric orientation for certification and life-cycle analyses could be a return to forestry's roots in European management paradigms, but it hardly seems like a good prescription for wise or efficient natural resource use in times of increasing resource scarcity. It will lead to less wood being available and to more use of alternative, energy-intensive resources.

Another concern is the impact on nonindustrial private forest landowners and markets. Timber markets consisting of NIPF owners (sellers) and forest industries (buyers) have a tenuous balance of power already. Timber buyers, who purchase wood all the time, know much more about timber measurement techniques and prices. Adding a new factor of certified wood and forestry into the equation will make this already fragile power balance tip even more toward timber buyers. Although it might serve as a means to increase timber prices for desirable wood, the lack of certification could be used as bargaining chip (or club) against less knowledgeable owners to depress the prices they were paid, whether it actually was the case or not. Timber buyers have been reported occasionally to scare NIPF owners into selling cheaply by intimating that insects or disease might kill an owners' trees. The same ploys could be used for uncertified wood. Even in cases when uncertified wood really was worth less, the cost surely would come out of the stumpage price paid to the NIPF owner, not out of the profits of the forest products companies. In addition, large companies will be better able to perform practices and audits that will allow their wood to be certified. This could contribute to a two-tier price structure favoring large companies and penalizing small timberland owners. The chain of control issues and costs will exacerbate the already difficult problems with NIPFs and possible reductions in their stumpage costs. If landowners do not perceive or receive adequate returns from timber investments, we may well have not only less timber, but also less overall management and environmental protection. There is some latent resentment against large forest products companies in some communities and by some landowners already. Having large companies act as timber certification and buying judge and jury at the same time will not create goodwill and might discourage landowners from making timber investments.

The role of consultants or small companies that provide forest certification or inspections could significantly affect market outcomes. At the very least, these concerns will become another player in market transactions. They will provide a service, probably at a significant cost, and either generate no more wood production or actually reduce wood production. More consultants and inspectors will be good for forestry schools and bureaucracies, but at some cost to society. At best, the environment will be better protected but landowners will receive slightly less return. At worst, landowners will have to pay large sums to certify environmental compliance, and perhaps even spend a significant amount of their own time in doing so, and receive much lower financial returns. The selection and implementation for sustainable forestry criteria and standards also has considerable potential for arbitrary and capricious rules that are based on bad science and will probably discriminate against growing and harvesting timber cheaply to promote unquantifiable environmental benefits. This concern again argues for truly voluntary programs, where only the landowners who want to will participate, and thus they alone can capture any gains that are available from certification. If everyone participates in certification, it will just raise costs without providing any benefits of market segmentation.

Conclusion

Forest products, life-cycle analyses, standards, certification, and labeling are excellent concepts that help ensure environmental protection and enhance market share in selected countries and for selected owners. These concepts should be approached through reasonable, voluntary, market-based mechanisms and applied to all industrial sectors—not just forestry. As this review indicates, however, there certainly are hazards involved with certification and strict standards for forest environmental protection. My role here is to serve as a critic of these concepts to prompt improvement. There is no shortage of advocates for life-cycle analyses, standards, certification, and green labeling. Indeed, this area promises to be the largest current growth industry in forestry consulting and management services. It also offers intriguing opportunities to mix market incentives for environmental protection with landowner desires to provide environmentally friendly management, for an incremental profit. However, to realize these potential Pareto-optimal outcomes, certification must rely on voluntary methods and responses as much as possible. Heavy handed or mandatory implementation of these methods, for all owners, will create huge market distortions, cause a loss of interest and investment in forestry, and shift production to other, more energy-wasteful activities.

There remains important work for the government in providing good information about the subjects of standards, life-cycle analysis, certification, and green labeling. Federal scientific and policy organizations should help analyze, plan, and develop means to establish good scientific efforts to measure the status and health of forest ecosystems, the merits of wood and other resources, and the means to dispassionately assess the relative merits of various resources for use. We need better information about resource use and protection, the effects of various certification programs on resource management and economics, and the integration of sound science into policy recommendations. These charters should provide considerable challenges but will be crucial in achieving the goals of sustainable economic development of all our forest resources.

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Life-Cycle Assessment and Certification Rapporteur's Perspective

BOB GLOWINSKI
American Wood Council of the
American Forest and Paper Association

I present my opinions here as a representative of the wood products manufacturers. I see a multidimensional matrix for the life-cycle analysis issue. There seem to be several components. There are the tools we need for inventory and impact analysis. We also have data needs that those tools will ultimately require. The matrix can be divided into the components in the full life cycle in which it will be used, those that occur in the forest, and those that occur from the manufacturing of the product. It seems that we have a range of capabilities that could be placed within that matrix for completing those tasks. I think we are progressing toward having inventory tools for the product, but I see very little, or hear very little, that persuades me to believe we have any kind of tools available for going back into the forest, to do the kind of analysis that life-cycle studies will eventually require.

Similarly, we have good data in some areas, bad data in others, no data in still others. It strikes me that projects like a follow up to the National Academy of Sciences 1976 report of the Committee on Renewable Resources for Industrial Materials (National Research Council, 1976) could go a long way toward filling some of the gaps in my matrix.

Industry generally fears regulation—not because regulation cannot be good or might be bad—but because regulations can be developed without sound underlying principles. That is the particular fear concerning the adoption of life-cycle analysis as the basis for regulatory control of the industry. Moreover, we would be concerned that voluntary regulations would quickly become mandatory—if it's regulatory it cannot be voluntary.

The tools so far developed to implement any type of regulation have not been developed in an open and transparent process, so little is known about how they work. It seems that there is not even agreement about whether the methodologies are based on sound science or whether they are more appropriately ascribed to "pseudoscience." To the extent that any type of regulatory implementation will result in increased costs, those costs will be borne by all of us—manufacturers and consumers alike. And if we are going to increase costs, it seems we ought to have a strong understanding and good reasons for any regulation that would be adopted.

Certification, which has been discussed in this volume as an undertaking, can act as de facto regulation. To the extent that we would adopt a voluntary implementation process, it seems it would be possible only when we all come to agreement that the underlying science and that the tools and analysis that underpin it have also been embraced and supported by those who can take advantage of it. Certainly, the International Organization for Standardization (ISO) certification process, which is perhaps being developed in more of an open and transparent system, must be watched carefully, because different groups obviously come to ISO with causes they wish to advance.

There are trade-offs and complexities. Life-cycle analysis cannot be reduced to a single number. The statement, "My product is better than your product," does not seem to fit well with the purpose of life-cycle analysis. As an industry, however, I believe our manufacturers would embrace some kind of analytical capability, whether life-cycle analysis or life-cycle inventories or something else altogether. It gives us, as manufacturers, the opportunity to develop better products. If we develop better products, the marketplace will react as a self-regulator. Better products generally rise to the top, and if we could use these tools to develop better products, we would see the opportunity to have a marketplace advantage.

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Implications of Life-Cycle Concepts
Rapporteur's Perspective

JOSEPH FIKSEL
Battelle Memorial Institute

I would like to begin by addressing a question posed in this volume. Is there a concern that life-cycle analysis (LCA) methodologies will become regulatory tools? The answer is a resounding yes. There is a second question. Are they adequate for use in regulation and policy making? The answer is a qualified no. My opinion, based on my observation of this field, is that existing methodologies for life-cycle assessment are immature; they do not adequately address the full range of issues reviewed in this volume. In particular, they are inadequate to assess environmental impacts such as ecosystem stability, sustainability, aesthetics, and biodiversity.

The current generation of life-cycle methods is well developed for a limited range of applications. We can do mass and energy balances fairly well, but we do not have very good methodologies for translating these mass and energy inventories into consequences or impacts on the environment. In fact, there is no scientific consensus on such methods; they are just beginning to be explored. The field is still somewhat embryonic—as mentioned in several of the presentations. As an example, the discussions presented in Chapter 8 and Appendix 1, concerning labeling and, more particularly, stress effect networks, reflect a body of thought that is still in its infancy. Therefore, we must be cautious about promulgating such methodologies for use in a regulatory context. On the other hand, the use of life-cycle *concepts* to guide regulatory policy is highly appropriate and can lead to more flexible, sensible regulations.

The field brings to mind the early days of risk assessment. I was involved 20 years ago in developing methodologies for assessing chronic human health risks associated with carcinogens and other substances in the environment. We started with science and we ended up with pseudoscience. Toxicology is a science, epidemiology is a science, but risk assessment, as practiced today, is not a science. It is a set of methodologies that is laden with uncertainties and assumptions, and the results cannot be verified because they predict such low incidences of effects that it would be impossible to statistically discriminate those effects in human populations. So we are dealing with an unvalidated theory. And yet, we see these methodologies aggressively promulgated and adopted by regulatory agencies, with the full support of Congress. The result is often a politicization of science involving acrimonious debate between various parties who have different interests with regard to the distribution or release of given products or substances. It would be a shame to take the field of life-cycle assessment and repeat this pattern.

There are other questions addressed in this volume, concerning how the use of life-cycle concepts could affect trade and consumer acceptance, among other areas. There are many concerns about having a "level playing field" in the debate over ISO 14000 and other international standards. Some nations may seek to impose more stringent criteria, thereby limiting imports of goods and favoring their own industries. Such protectionist trade policies could be exacerbated by the accelerated adoption of life-cycle analysis. One can envision criteria that might not be scientifically defensible, but would be convenient for certain interest groups or nations. The potential for abuse exists both on the regulatory front within the United States, and on the international front in terms of use of LCA for eco-labeling.

Jacques Besnainou's chapter on the European methods (Chapter 4) discusses the limitations of life-cycle analysis for broad generalization and the problem of spatial and temporal resolution. One problem he does not include is that life-cycle analysis does not treat the science of economics at all. In fact, the approach of life-cycle assessment was deliberately developed without consideration of economic impacts. So its seems that if you try to use it as a policy tool, half of the equation is missing. Some of the most important effects of stating preferences for different kinds of materials or for making judgments about acceptability of products and processes are economic. And they are highly visible—on employment, on productivity, on gross domestic product. There is tremendous potential for abuse when tools that aggregate subjective judgments are put together with quasi-scientific results and are used to justify one approach over another—especially when economic effects are deliberately excluded. We live in a dynamic market system and we must understand how markets will respond to these kinds of products.

Another question: What will be consumer acceptance? Most industries have found that consumers are by-and-large indifferent to “green products.” There’s a small segment of the marketplace—perhaps less than 5 percent—that is more responsive. But many manufacturers have found they cannot charge a premium for green products. If all else is equal, consumers might favor a green product over another, but in general they are somewhat vague about why. Therefore, the language of LCA is more useful for initiating dialogue between government and industry than it is for purposes of communications with the marketplace. Consumers are primarily interested in the performance and price of products—and most prefer to trust government to sort out some of the more complex issues regarding environmental impacts. Unfortunately, there is a good amount of mistrust today, and that is why many consumer groups are suspicious of scientific methods endorsed by government or industry. I believe that the average consumer would rather have someone else do the work to create adequate policies and regulations that protect against truly harmful effects.

In conclusion, it seems that there is a logical next step. There should be a broad study to pull together the diverse research in this field in order to better explain “industrial ecology” and the broad consequences of materials production and processing, and to establish sound scientific principles both for directing the development of methodology and for critiquing proposed methodologies that might arise in different contexts. A framework could then be identified to support a variety of research projects in different disciplines, including ecology, biology, economics, and environmental sciences. Such a study could also identify ways to bridge the gaps and bring together the results of those research efforts within a coherent framework. This could accomplish for LCA what the National Academy of Sciences has done in the area of risk assessment, in its attempt to bring some reasoned scientific perspective into the synthesis of science with subjective values.

APPENDIXES

APPENDIX 1

Annex 1: Life-Cycle Stressor Effects Assessment

Effective implementation of international standards for environmental management, auditing, performance evaluation, and labeling depends in part on the availability of a quantitative, cradle-to-grave environmental assessment tool. Within the ISO-14000 series, life-cycle assessment is the one methodology that has demonstrated the greatest potential for addressing this need.

The life-cycle impact assessment (LCIA) standard is intended to guide practitioners and users in assessing potential environmental effects associated with specific industrial systems. The standard outlines a general "inventory interpretation" approach to LCIA in which potential system impacts are predicted on the basis of inventory analysis data. (Inventory analysis data are input–output data that have been aggregated and allocated without consideration of their spatial, temporal, threshold, and dose–response characteristics, and without regard to the magnitude of the actual environmental effects.)

As described in the standard, life-cycle analysis users must be cautioned that such an approach cannot, in and of itself, provide an accurate portrayal, or even an approximation, of the actual effects caused by the industrial system being studied. The standard further advises life-cycle analysis users that, to understand the actual environmental effects of a system, the findings should be considered in conjunction with environmental data typically generated by site-oriented environmental assessments, such as Environmental Impact Assessments (EIA).

This annex describes an approach to LCIA that merges the cradle-to-grave accountability of life-cycle analysis with the assessment of stressor-effects networks and consideration of relevant spatial, temporal, threshold, and dose–response characteristics common to other environmental assessment disciplines. Specifically, the life-cycle stressor effects assessment (LCSEA) approach is designed to perform the iterative calculations required to determine the significance and relative contribution of an industrial system's inputs, outputs, and activities to actual measurable or observable environmental effects. Its purpose is to provide practitioners, industrial users, and other interested parties with a practical application of the proposed LCIA framework, free from the arbitrary allocation and aggregation procedures associated with inventory analysis data.

LCSEA UNIT OPERATION

Within the life-cycle inventory, the term "unit operation" refers to individual physical processes or groups of processes that produce a single product or service and their associated inputs and outputs. The input–output data for each unit operation are typically normalized with respect to mass units of production, then averaged over a selected period (for example, 12 months) to account for fluctuations in industrial processes. Once normalized and averaged, the input and output data for all unit operations of the system are aggregated and allocated to produce an overall mass and energy balance.

Just as life-cycle inventory models link unit operations, the LCSEA architecture is based on LCSEA unit operations linked by process. In addition, LCSEA unit operations are linked by effect. The LCSEA unit operation is distinguished from the standard life-cycle inventory unit operation in several respects, as described below. Because the objective of the LCSEA approach is to quantitatively assess the significance and contribution of an industrial system's effects on the environment, each LCSEA unit operation is defined in terms of its relevant stressor-effects networks.

USEFUL COMPONENTS OF LCI

As described in Figure A-1, the physical boundaries of the LCSEA unit operation generally correspond with the boundaries of a standard LCI unit operation. Appropriately aggregated input and output data associated with the standard LCI unit operation provide the initial set of useful data for the LCSEA unit operation. These input–output data are classified into corresponding stressor effects networks.

NEW COMPONENTS OF THE LCSEA UNIT OPERATION

To determine the full array of stressor effects networks relevant to the system being studied, however, it is necessary to look beyond the standard life-cycle inventory input–output data. Some stressor effects networks do not have direct input or output causes, but are nevertheless related to the activities of a system and can be measured through quantifiable effects indicators. For example, mechanical disruptions that occur at mining sites can cause effects, even though inputs or outputs are measured under a standard life-cycle inventory.

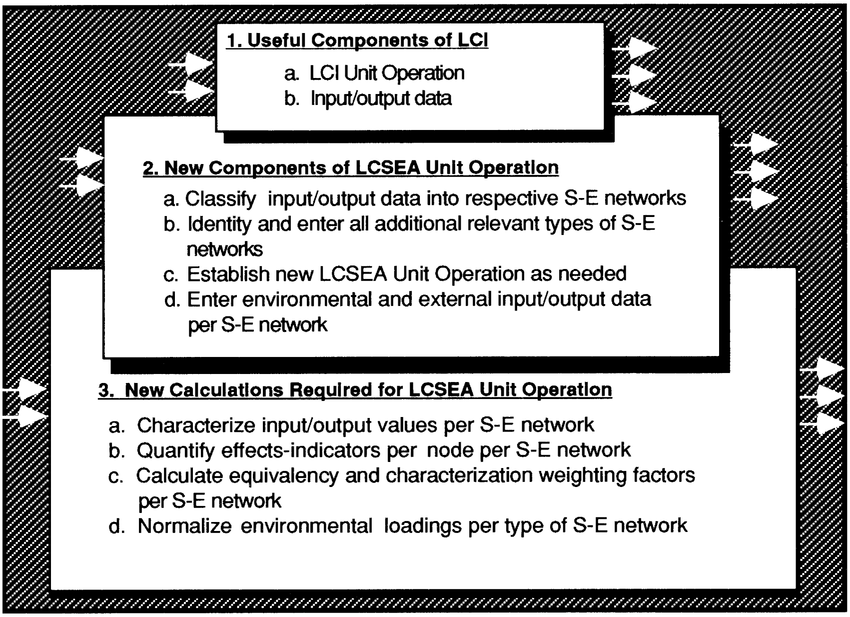

FIGURE A-1 Useful components of a life-cycle inventory.

Effects indicators are calculated only from environmental data, which are not currently being collected under for life-cycle inventories but that are routinely collected for other environmental assessments. The LCSEA approach is the first life-cycle analysis approach specifically designed to integrate such data into the architecture. It is the inclusion of these environmental data that transforms life-cycle analysis from a tool used simply to model potential impacts into a tool that assesses the actual effects of a system.

Environmental data describe the spatial, temporal, threshold, and dose–response characteristics of input–output values and effects indicator values with respect to their relevant stressor effects networks. For example, for the eutrophication stressor effects network, environmental data include the baseline percentage of dissolved oxygen (2 percent) in a lake and the reduced percentage (0.2 percent) of dissolved oxygen in that same lake at a later date. These data, in turn, are used to characterize the effects indicator for the LCSEA unit operation—in this case, a 90 percent decrease in dissolved oxygen.

Environmental data also are used to normalize input–output values and effects indicator values to quantify their significance and contribution to a given effect. In the eutrophication stressor effects network example, external input–output data, such as the amount of phosphate emissions from other sources into the same lake, are needed to determine the relative contribution of the system's phosphate emissions to the total effect.

In some instances, life-cycle inventory models have aggregated input–output data from multiple unit operations under one unit operation. In other instances, specific unit operations with no measured inputs or outputs have been excluded from life-cycle inventory models. In such cases, environmental data provide the sole route for identifying relevant stressor effects networks, thereby triggering the need to create new LCSEA unit operations.

NEW CALCULATIONS REQUIRED FOR THE LCSEA UNIT OPERATION

The new components of the LCSEA unit operation described above make possible, for the first time, the ability to

- determine the significance and contribution of each raw input–output data point to actual effects,
- identify specific nodes in the stressor effects networks associated with a given unit operation and quantify the magnitudes of their respective effects indicators,
- establish quantitative equivalency factors and characterization weighting factors with established levels of certainty,
- calculate the "environmental loadings" for each LCSEA unit operation per stressor effects network on a functional unit basis, and
- calculate the cumulative environmental loadings for the system, product, or service being studied.

Equivalency Factors and Weighting Factors

Because life-cycle analysis as historically practiced has been confined to inventory analysis and the assessment of potential impacts, users have been limited in their ability to establish meaningful equivalency and weighting factors. The LCSEA approach, in which a system's actual contribution to effects is assessed, allows new equivalency and weighting factors to be established:

- The relative aggregated magnitude of a specific input–output to a related group of inputs–outputs within a specific stressor effects network (e.g., molar acid equivalencies for outputs associated with acid rain).
- The relative magnitude of the effects in a specific stressor effects network compared with effects in other stressor effects networks of the same type.
- The relative magnitude of the effects of a specific stressor effects network compared with effects in similar types of networks (e.g., networks with the same endpoint effect).

Establishing the LCSEA Functional Unit

An essential architectural feature of standard life-cycle inventory engineering models is that each unit operation is a stand-alone module. An individual unit operation can be linked through the functional unit to any other unit operation to calculate the mass and energy balance for a given system, product, or service. In life-cycle inventory engineering studies, the aggregated inputs and outputs are typically allocated on a direct proportional basis by mass to the functional unit—per kilogram, MJ, kWh, or mile driven, for example. However, from an actual effects perspective, such a linear proportional relationship most often does not exist.

Like its life-cycle inventory counterpart, the LCSEA functional unit allows for the same critical linking of unit operations in a system. Accordingly, LCSEA functional units are also divided through on a per kilogram, MJ, kWh, or mile driven basis. The essential difference is that LCSEA unit operations are linked not only by process but by the significance of the various measurable effects. The environmental loadings (the normalized inputs–outputs and effects indicators) are allocated by effect to the functional unit.

Thus, the LCSEA is constructed as follows (WF is the weighing factor; EF is the equivalency factor):

$$\text{Reported environmental loadings per LCSEA unit operation} = \frac{\text{(Inputs, outputs, effects indicators) x (EF or WF)}}{\text{kilogram of product used, etc.}}$$

Overall LCSEA Environmental Loadings for a Given Study

Once the normalized input–output and effects indicator loadings per unit operation have been established, the cumulative environmental loadings can be calculated for the entire system or for the specific material, product, or service being studied. The calculation of overall environmental loadings is essential for such LCA applications as Type III labeling and the establishment of quantified environmental performance indexes.

CRITICAL TERMS AND DEFINITIONS FOR ANNEX 1

Raw Input–Output Data

The amount of material or energy used or the amount of releases into air, water, or ground from a given unit operation, without regard to any specific environmental effects.

Effects Indicator

A physical, chemical, or biologic measure of a specific node within a recognized stressor effect network.

External Input–Output Data

Raw input–output data related to operations that are used to determine the contribution of the system inputs–outputs to effects in a given stressor effects network, but that are unrelated to the system defined by a given study.

Stressor

A physical activity, or physical or chemical input or output that can trigger a subsequent environmental effect or network of effects.

Environmental Data

The data needed to classify, characterize, or normalize input–output data, or to quantify effects indicators, for each stressor effects network associated with a given unit operation.

Endpoint Effect

The explicit measurable or observable effect in the environment which identifies the assessment endpoint as relevant and meaningful and allows the significance of the impact assessment results to be evaluated.

Stressor Effects Network

The sequential physical, chemical, or biologic mechanisms involved in linking a specific stressor to specific environmental effects.

Equivalency Factor

Characterization factor based on a recognized, well-defined stressor effects network and well-established properties of the stressors involved.

Characterization Weighting Factors

Subjective factor that translates individual stressors into a relative ranking or weighting scheme. It may then be possible to mathematically represent the effective loadings of a stressor effects network.

Normalized Input–Output Value

A value that represents the relative significance of input or output from a unit operation for the relevant stressor effects network for a given function.

Environmental Loading

Normalized input–output loadings and effects indicator loadings.

LCSEA Unit Operation

An industrial process within the scope of a given life-cycle study, and its associated stressor effects networks defined with respect to their spatial, temporal, threshold, and dose response characteristics.

Sensitivity Analysis

A systematic process to define and evaluate the effect of variations of inventory and model data input on the impact assessment result.

Uncertainty Analysis

A systematic process for defining and evaluating the sources of error and uncertainty in the impact assessment process, including the linkage of stressor effects networks and their inherent characteristics, such as space, time, dose response, and threshold.

APPENDIX 2

Symposium Program

MODERATORS

John Antle, *Montana State University*
Frank Beall, *University of California*
Eric Ellwood, *Dean Emeritus, North Carolina State University*
Joseph Fiksel, *Battelle Memorial Institute*

BREAKOUT GROUP LEADERS

David Briggs, *University of Washington*
Sergio F. Galeano, *Georgia-Pacific Corporation*
Dana Harmon, *Wood Reduction Clearinghouse*
William J. Nicholson, *Potlatch Corporation*
W. Ramsay Smith, *Louisiana State University*

ROUND TABLE PANEL

William Bentley, *Salmon Brook Associates*
Frederick Cubbage, *North Carolina State University*
Joseph Fiksel, *Battelle Memorial Institute*
Bob Glowinski, *American Forest & Paper Association*

PROGRAM

Environmental Implications of Wood as a Raw Material for Industrial Use

March 14 and 15, 1996
Agenda
National Academy of Sciences and Engineering Beckman Center
Irvine, California

THURSDAY, MARCH 14, 1996

8:00 a.m.	Introduction *Eric Ellwood, Dean Emeritus, North Carolina State University and Chair, National Research Council's Board on Agriculture's Symposium Steering Committee*
8:15-8:45	Keynote Address *Bernard Yaros, Technology Manager* *Scott Paper Company*
Session I	**Accounting Methodologies** *Moderator: Frank Beall, University of California*
8:45-9:30	Committee on Renewable Resources for Industrial Materials (CORRIM): A Look Back and Consideration of the Future *James Bowyer, National Academy of Sciences' 1976 Committee on Renewable Resources for Industrial Materials, and University of Minnesota*
9:30-10:15	Methodologies for Assessing Environmental Impacts of Wood Used as a Raw Material in North America *Derek Augood, Battelle Memorial Institute*
10:15-10:45	BREAK
10:45-11:30	Methodologies for Assessment in Other Countries *Jacques Besnainou, Ecobalance*
11:30-12:15	Considerations on the International Organization for Standardization (ISO) *Lynne Anderson, Chair ISO 14,000 West Coast Working Group*
12:15-1:30 p.m.	LUNCH

Session II	**Societal Considerations** *Moderator: John Antle, National Research Council's Board on Agriculture and Montana State University*
1:30-2:00	Industrial Marketplace Product Decision Making *Mark Eisen, Home Depot*
2:00-2:30	Environmental Considerations *Richard Denison, Environmental Defense Fund*
2:30-3:00	Green Labeling and Consumer Acceptance *Stanley Rhodes, Scientific Certification Systems, Inc.*
3:00-3:30	Impact Assessment Applied to Environmental Decision Making *Sergio Galeano, Georgia Pacific Corp.*
3:30-4:00	BREAK
4:00-5:00	Reconvene in Break Out Group Rooms *Rapporteurs appointed for each break out group*
5:30-8:00 p.m.	RECEPTION

FRIDAY, MARCH 15, 1996

8:00 a.m.	Individual Reports from Break Out Groups
9:30-10:00	Summary of reports: conclusions, difficult areas
10:00-10:30	BREAK
Session III	**Beyond Academics** *Moderator: John Antle, National Research Council's Board on Agriculture and Montana State University*
10:30-11:00	Policies Today and for the Future *Bill Hyde, Virginia Polytechnic Institute and State University*

11:00-12:15 Round Table Discussion
Led by a panel:
William Bentley, Salmon Brook Associates;
Frederick Cubbage, North Carolina State University;
Joseph Fiksel, Battelle Memorial Institute;
Bob Glowinski, AF&PA

12:15-12:30 p.m. Closing Comments
Eric Ellwood

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