Catalogue no.16-505-GIE

Concepts, Sources and Methods of the Canadian System of Environmental and Resource Accounts

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	Single issue
United States	CAN$6.00
Other countries	CAN$10.00

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Statistics Canada

Environment Accounts and Statistics Division
System of National Accounts

Concepts, Sources and Methods of the Canadian System of Environmental and Resource Accounts

Published by authority of the Minister responsible for Statistics Canada

April 2006

Catalogue no. 16-505-GIE
ISBN 0-662-38957-3

Catalogue no. 16-505-GPE
ISBN 0-660-17128-7

Frequency: Occasional

Ottawa

Version française de cette publication disponible sur demande (n°16-505-GIF au catalogue).

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Symbols

The following standard symbols are used in Statistics Canada publications:

..	figures not available
...	figures not appropriate or not applicable
-	nil or zero
- -	amount too small to be expressed
e	estimate
p	preliminary figures
r	revised figures
x	confidential to meet secrecy requirements of the *Statistics Act*
nec	not elsewhere classified

Concepts, Sources and Methods of the Canadian System of Environmental and Resource Accounts

Table of Contents

Preface

In the past, many Canadians took their natural heritage for granted. They viewed the environment as an almost limitless source of raw material to be exploited and fed to a growing economy. The pollution that inevitably accompanied this growth, to the extent that it was considered at all, was assumed to be dealt with by nature's equally unlimited waste absorption capacity.

This perception has changed. Canadians, like people in many other countries, have come to understand that the capacities of their environment to supply materials and absorb wastes are finite. They now recognize that these capacities must be respected and safeguarded if future generations are to enjoy the same level of environmental benefits that we enjoy today. Equally important, Canadians today realize that the environment has value beyond its direct use by humans. Preserving wildlife habitat, for example, has become a primary motivation for calls to protect the environment.

This growing environmental awareness has led to demands for new kinds of information. Beyond traditional measures of economic activity, Canadians are now asking for measures highlighting the relationship between the economy and the environment. In response to this demand, the Government of Canada–under the auspices of *Canada's Green Plan* (Government of Canada, 1990)–asked Statistics Canada in 1991 to initiate development of a system of environmental and resource accounts that would quantify the links between the environment and the economy. The new **Canadian System of Environmental and Resource Accounts** (CSERA) described in this volume is the result of this initiative.

Although the notion of quantifying and valuing the environment is not new–discussions and theories have been around for at least 60 years–only since the early 1970s has there been a concerted effort by national statistical organizations toward the development of formalized systems for this purpose. The Canadian initiative to develop environmental and resource accounts had its origins with exploratory work carried out during the late 1970s and early 1980s (Friend and Rapport, 1979; Friend, 1981). At that time, data representing the interactions between human activity and the environment were recorded using the Stress-Response Environmental Statistical System. This framework had as its focus the physical measurement of the environment's response to various human stresses. Although useful as a means of organizing physical data, the framework did not attempt to incorporate monetary data or to provide links to the economic variables most often employed in policy development; namely, the variables of the **Canadian System of National Accounts** (CSNA).[1]

Building on this early work, the CSERA has been developed with the specific objective of organising physical *and* monetary statistics related to natural resources and the environment using classifications, concepts and methods that are compatible with those of the CSNA. Thus, the statistics of the CSERA can in large part be directly integrated with those of the CSNA. The integration of these two data sets–one environmental, the other economic–represents a significant milestone in Statistics Canada's capacity to assess economic activity and its dependence upon the natural environment. This new capacity is particularly relevant today, given the increasing focus of governments, businesses and individual Canadians on the objectives of sustainable development.

Although well established both conceptually and empirically, the CSERA remains a work-in-progress. The current scope of the system represents only a portion of what a complete set of environmental and resource accounts for Canada would cover. The present volume thus outlines not only what has been accomplished to date in the development of the system, but also the work that remains for the future. Rather than being viewed as the final word on the development of the CSERA then, this volume should be seen as a "snapshot" of the state of its development as of the autumn of 1997. The system will continue to evolve in step with our understanding of the interaction between the economy and the environment; this volume will be periodically updated to reflect this evolution.

Organization of this volume

Divided into five chapters, the present volume describes the concepts, data sources and methods used to date in the development of the CSERA.

The introductory chapter is intended to provide those readers wishing to familiarize themselves with the CSERA, but without the time to read this volume in its entirety, with an overview of the system and some the most important underlying concepts. The chapter begins with a brief introduction to the system, followed by a discussion of the relationship between environmental and resource accounts and national accounts in general. More detailed presentations of each of the three principle components of the CSERA are given next. These are followed by an examination of the economic interpretations of sustainable development and their implications for the system. The chapter ends with a discussion of future directions for the CSERA.

Chapter 2 presents brief descriptions of some of the major environmental and resource accounting initiatives underway in other industrialized countries.

Chapters 3 through 5 are devoted in turn to detailed descriptions of the three principal components of the CSERA:

1. The CSNA, which has a history of more than 40 years, is the source of a number of Statistics Canada's most important indicators of economic activity, including Gross Domestic Product. Readers unfamiliar with this system are referred to *A User Guide to the Canadian System of National Accounts* (Statistics Canada, 1989b) for an overview.

- the Natural Resource Stock Accounts (Chapter 3);
- the Material and Energy Flow Accounts (Chapter 4); and
- the Environmental Protection Expenditure Accounts (Chapter 5).

A detailed reading list is included at the end of the volume for those wishing to delve more deeply into the literature on environmental and resource accounting. A glossary of key terms and abbreviations is also provided to aid readers unfamiliar with the language used in the field.

About *Econnections*

The series title under which this volume is published, *Econnections: Linking the Environment and the Economy*, is new for Statistics Canada. It has been coined for a suite of statistical products that will elaborate the connections (or linkages) between economic activity and the natural environment. This elaboration will be achieved by means of a wide variety of physical and monetary statistics, both detailed and summary, that will be made available to Canadians in print and electronic formats. These statistics will be offered in the guise of a number of products, focusing on an annual publication of summary environment-economy indicators accompanied by a CD-ROM database containing detailed statistical times series.[1] Many of the indicators and statistics presented in this annual publication/database are derived from the CSERA, as will be explained in detail in the pages that follow.

The *Econnections* logo appearing on the cover of this volume has been conceived to convey the notion that the economy is inextricably tied to the natural environment; that the environment is the physical foundation upon which the economy rests. All Statistics Canada products that fall within the *Econnections* series will bear this logo to identify them as offering statistical information relevant to understanding the linkages between the economy and the environment.

Acknowledgements

This volume, and the accounting system that it describes, have been prepared by the Environmental Statistics sub-division of the National Accounts and Environment Division under the direction of Philip Smith (Director, 1990-1995) and Claude Simard (Director, 1995-present). Robert Smith served as production manager and editor for the publication. Major contributions to the conceptual and empirical development of the CSERA have been made by:

Cynthia Baumgarten
Michael Bordt
Alice Born
Giuseppe Filoso
Craig Gaston
Yvan Gervais
Gerard Gravel
Kirk Hamilton
Tony Johnson, Australian Bureau of Statistics
Anik Lacroix
Marc Lavergne
Greg Lawrance, Ontario Ministry of Natural Resources
Martin Lemire
Deborah MacDonald
Bruce Mitchell
Richard Moll
Rowena Orok
Marcia Santiago
Robert Smith
Doug Trant
Michael Wright

The technical support of the following people in the areas of marketing, proofreading, translation and dissemination is gratefully acknowledged:

Isabelle Bégin
Anne-Marie Bridger
Mitzi Ross
Hélène Trépanier
Vie Weatherbie

The support of several divisions within Statistics Canada and in other federal and provincial government departments is also gratefully acknowledged:

Agriculture and Agrifood Canada; (Eastern Cereal and Oilseed Research Centre, Land Resource Evaluation Section); **Environment Canada** (Indicators and Assessment Office; Pollution Data Branch); **Ontario Ministry of Natural Resources**; **Natural Resources Canada** (Canadian Forest Service; Minerals and Metals Sector; Uranium and Radioactive Waste Division; and Energy Resources Branch); **Statistics Canada** (Agriculture Division; Geography Division; Input-Output Division; Investment and Capital Stock Division; Manufacturing, Construction and Energy Division; and Public Institutions Division).

1. The first edition of the *Econnections* indicators publication/database is available under the volume title *Indicators and Detailed Statistics 1997* (Statistics Canada, Catalogue No. 16-200-XKE).

1 Introduction and Overview

Introduction

Comprising three major components, the **Canadian System of Environmental and Resource Accounts** (CSERA) represents a comprehensive framework for linking the economy and the environment through physical and monetary statistics. The three components of the framework are introduced below; more detailed descriptions of each component are presented in Section 1.2.

- The **Natural Resource Stock Accounts** measure quantities of natural resource stocks and the annual changes in these stocks due to natural and human processes. These accounts, which are recorded using both physical and monetary units, form the basis of the estimates of Canada's natural resource wealth that are included in the Canadian National Balance Sheet Accounts. Chapter 3 of this volume is devoted to a detailed presentation of the accounting concepts, data sources and methods used in compiling the Natural Resource Stock Accounts.
- The **Material and Energy Flow Accounts** record, in physical terms only, the flows of materials and energy–in the form of natural resources and wastes–between the economy and the environment. The Material and Energy Flow Accounts are linked directly with the Input-Output Accounts. This linkage allows the calculation of important indicators of the resource and waste intensiveness of economic activity. Chapter 4 is devoted to a detailed presentation of concepts, sources and methods used in the Material and Energy Flow Accounts.
- Finally, the **Environmental Protection Expenditure Accounts** identify current and capital expenditures by business, government and households for the purpose of protecting the environment. These accounts measure both the financial burden associated with environmental protection, plus the contribution of environmental protection to economic activity from a demand-side perspective. Chapter 5 presents the concepts, sources and methods used in the compilation of the Environmental Protection Expenditure Accounts.

The structure of the CSERA and the relationships of its components to the **Canadian System of National Accounts** (CSNA) are illustrated in Figure 1.1. It can be seen from this figure that several components of the CSERA actually fit within the framework of the standard national accounts. The Environmental Protection Expenditure Accounts in particular (row 4 in Figure 1.1) are simply a decomposition of the existing current and capital accounts for businesses, households and governments to explicitly show expenditures for environmental protection. Similarly, the Natural Resource Stock Accounts when measured in value terms (column D) are an extension of the current Canadian National Balance Sheet Accounts to include the values of some of the natural resource assets provided by the environment. The remaining components of the CSERA fall outside of the standard framework because they are not measured in value terms and/or because they measure flows that take place outside of the boundary of marketplace activity that defines the scope of the national accounts.

Much of the statistical information in the CSERA is measured in physical units rather than, or as well as, in monetary terms. In most cases, physical measurement of stocks and flows is a necessary first step even if the ultimate objective is to measure monetary values. The measurement of physical stocks and flows is also more objective and less controversial. Still, the assignment of monetary values to natural resource assets is desirable, as it facilitates the aggregation and comparison of diverse asset types. Considerable effort is given to estimating monetary values for natural resource assets in the CSERA. The many conceptual and practical issues associated with the valuation of natural resources are covered in detail in Chapter 3 of this volume.

Before continuing with a more detailed presentation of the CSERA and its component accounts in Section 1.2, a general discussion of environmental and resource accounts and their relationship to the standard national accounts is in order.

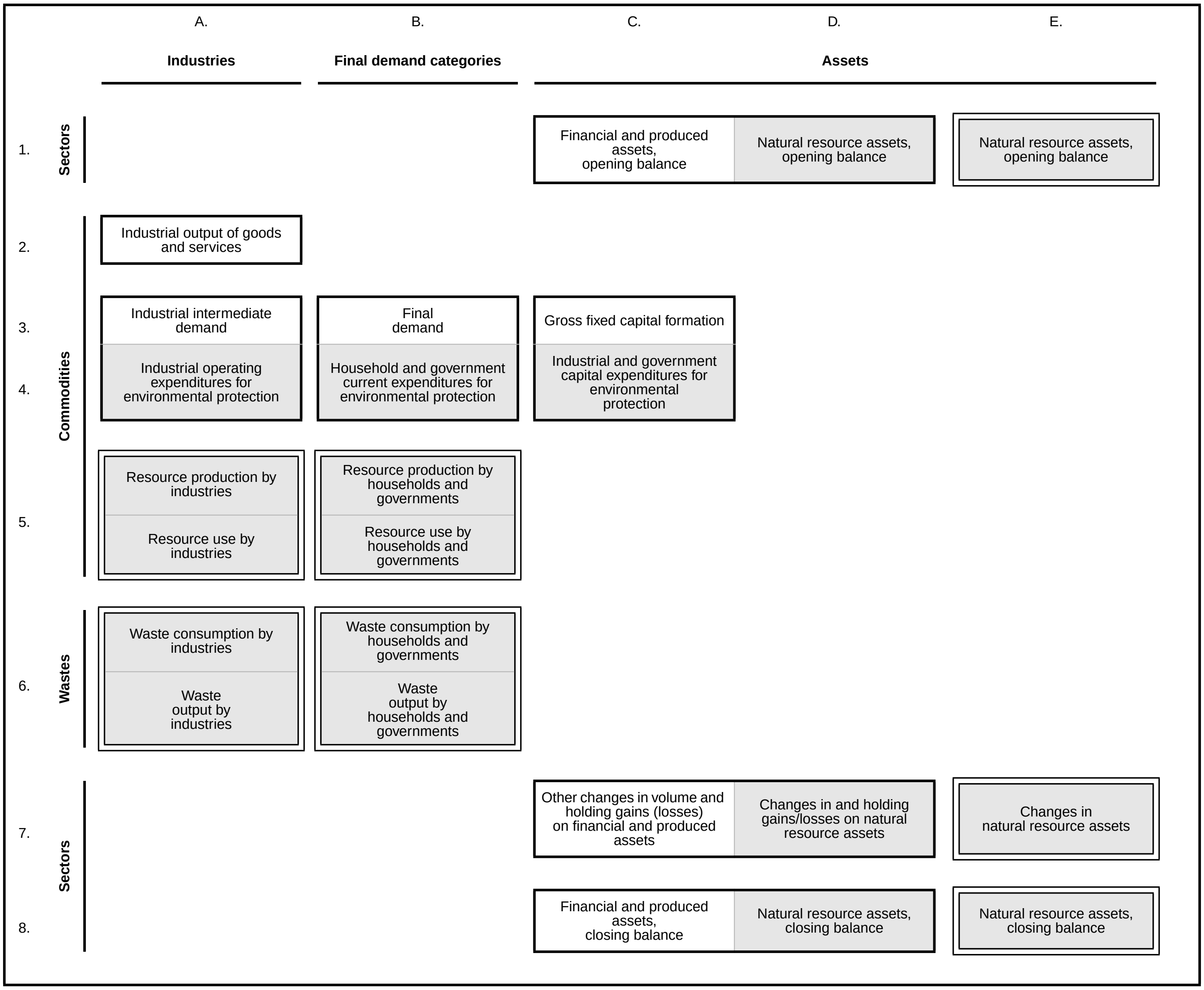
1.1 Environmental and resource accounts

Environmental and resource accounts can be defined as any systematic compilation of stock, flow or state statistics relating to the environment or to natural resources. To qualify as accounts, these compilations must adhere to predefined principles that specify:

- what is, and what is not, to be measured;
- what units of measure are to be used;
- how often measurement is to be undertaken;
- the geographic scope for measurement; and
- the format in which results are presented.

Taken together, the above elements define what may be called an accounting framework. Although environmental and resource accounts can be compiled according to any suitable framework, it is often the case that they use that of the national accounts. This framework is chosen, in part, so that the statistics of the environmental and resource accounts may be directly linked with those of the national ac-

Figure 1.1
The Canadian System of Environmental and Resource Accounts within the National Accounts



Note:
Unshaded boxes represent the core accounts of the standard Canadian System of National Accounts. Shaded boxes are the components of the CSERA. Solid borders indicate measurement in value units; hollow borders indicate measurement in physical units.

counts.[1] This linkage enhances the usefulness of both data sets.

The development of environmental and resource accounts joined to the national accounting framework has burgeoned during the past decade. Yet the idea of linking environmental and economic data through this framework is not new. Indeed, recognition of the need for this type of accounting extends back at least as far as the 1950s. An early advocate was the Canadian economist Anthony Scott (1956), who wrote:

> Because the total [wealth associated with] resources can be so important, there is reason to argue not only that totals of national wealth should give considerable attention to the extent of natural wealth, but also that the *national accounts* should annually show changes in this total (emphasis in the original).

A decade or more later, coincident with the first world-wide wave of environmental concern, a number of academic economists began investigating the possibility of integrating

1. Although the national accounts of every country have their own unique characteristics, many elements are common to the accounts of all nations. Thus, one can speak in general terms of "the national accounting framework," even though there is more than one such framework in use around the world.

environmental data into input-output accounts[1] (Cumberland, 1966; Daly, 1968; Isard, 1969; Ayres and Kneese, 1969; Leontief, 1970; and Victor, 1972). Several robust conceptual frameworks, as well as some empirical results, were presented at the time. It was not until later in the 1970s, however, that national statistical offices began the formal development of environmental and resource accounts. Norway (Alfsen *et al.*, 1987) and France (Weber, 1983) were the first to initiate such development, beginning their accounts in the mid to late 1970s. There was little formal activity on this front by other statistical organizations until the following decade.

The 1980s saw tremendous growth in the attention paid to integrating environmental and economic concerns in decision making. The highly influential World Commission on Environment and Development (the so-called Brundtland Commission) recognized the need for integrated environmental and economic accounting in 1987 with its call for “an annual report and audit on changes in environmental quality and in the stock of the nation’s environmental resource assets.” Such reporting, the Commission noted, is “essential to obtain an accurate picture of the true health and wealth of the national economy, and to assess progress towards sustainable development” (World Commission on Environment and Development, 1987; p. 314).

About the same time that the Brundtland Commission released its report, a number of other influential studies calling for the need to integrate environmental considerations into the national accounts appeared (Ahmad *et al.*, 1989; Daly and Cobb, 1989; and Repetto *et al.*, 1989 for example). By this time, many countries, including Canada, had begun to follow in the footsteps of France and Norway, formulating and implementing their own environmental and resource accounting frameworks.

The flurry of activity during the 1980s and first half of the 1990s has led to the situation where today many industrialized countries, and a growing number of developing nations, can claim a well-established set of environmental and resource accounts. Most, if not all, of these are linked to some extent with the national accounts of their respective countries.[2] In Canada’s case, conceptual work in the field began in the early 1980s (Friend and Rapport, 1979; Friend, 1981), with formal development of the accounts beginning in 1992.

Why a national accounting approach?

The focus on the national accounting framework in the development of environmental and resource accounts can be explained by a number of factors.

- The national accounting framework is well-established, having a history of more than 40 years of implementation around the world. Almost every nation compiles a set of accounts that follow this framework, if not in its entirety, at least in its major outline. This lends to the national accounts the appeal of a ready-made and internationally comparable information system with which to link environmental statistics.
- The national accounts are a very influential source of economic information. What is arguably the most widely quoted and used economic indicator available, the Gross Domestic Product, is a product of the national accounts. Other important indicators derive from the accounts as well; measures of wealth and indebtedness, savings rates, and labour productivity for example. These indicators are regularly used in the development of economic policy in both the public and private sectors. Environmental information linked with the national accounts can, therefore, be quickly and easily integrated into existing economic decision-making processes. This increases the likelihood that environmental information will be considered in such processes.
- Perhaps the most important reason why the development of environmental and resource accounts has revolved around the framework of the national accounts is the desire by statistical agencies to address long-standing environmental criticisms of the national accounts. These criticisms are well-known, having been exceptionally well documented in the literature, and do not require extensive reiteration here.[3] Briefly, they include neglecting to measure the contribution of the environment to national wealth; treating the receipts from the depletion of natural resources as current income rather than capital depletion; measuring the benefits of the use of the environment but not the costs; and including expenditures to protect the environment as part of gross production. Many of these criticisms are controversial and not all are accepted as legitimate by all parties to the debate. Nevertheless, most countries have attempted to address one or more of them in their environmental and resource accounts.

An important outcome of the activity in the field of environmental and resource accounting in recent years has been the integration of environmental considerations into the latest international guidelines for the development of national accounts. These changes are described next.

1.1.1 The *System of National Accounts 1993* and the environment

The internationally accepted set of guidelines for the preparation of national accounts is **The System of National Accounts 1993** (Commission of the European Communities *et al.*, 1993).[4] This substantial work represents the efforts of

1. Input-output accounts are a component of the national accounts in many countries. For more details, see Statistics Canada (1987) and Miller and Blair (1985).
2. Chapter 2 presents brief overviews of several environmental and resource accounting initiatives in the world today.
3. Daly and Cobb (1989) provide an excellent overview of these criticisms.
4. Hereafter this work is abbreviated as the SNA93.

five international economic organizations to define the scope of the national accounts and provide guidance on the concepts and methods that should be used in their compilation.

For the first time since such international guidelines have been published,[1] the SNA93 explicitly discusses the incorporation of environmental information into the national accounts. In fact, two sets of environment-related guidelines are presented. The first set deals with the incorporation of natural resource assets into balance sheet accounts. The second set, which is more far-reaching, describes the development of a “satellite system for integrated environmental and economic accounting.” Each of these advances is discussed below.

Natural resources and the national balance sheet

National balance sheet accounts are statements, drawn up for the end of the calendar year, of the values of financial and non-financial assets owned by the economic agents of a country and of the net financial liabilities against those same agents. Such accounts are normally drawn up for broad sectors of the economy (businesses, persons, governments and non-residents). They show the economic status of each sector; that is, the financial and tangible assets at its disposal. For the economy as a whole, the national balance sheet presents an aggregate measure known as national wealth–the sum of the values of the non-financial assets held by all domestic sectors of the economy.[2]

National wealth is an important economic indicator. It represents the value of the economic resources (or capital) from which the nation derives its future income. Exclusion of natural resource assets from balance sheet accounts, as has been standard practice to date in all countries, understates this income-generating capacity. While the value of the machinery and equipment used, for example, in timber harvesting has been included on national balance sheets, the value of timber resources themselves has not.[3] This asymmetry cannot be justified on economic grounds, as both types of assets, “produced” and “natural,” represent capital from which the nation can generate future income. Ignoring natural capital means ignoring a portion of the income-generating potential of the nation.

Exclusion of natural resources from national balance sheets leads to the situation in which the national accounts show no change when resources are depleted or degraded. Thus, a nation could, in theory, deplete its natural resource base entirely–losing the associated income-earning potential in the process (not to mention the loss of environmental heritage)–without a parallel loss appearing in its economic accounts. Clearly, the national accounts do not provide appropriate economic signals when such a loss is allowed to go unmeasured.

The previous version of the SNA guidelines, published in 1968, “did not include much guidance on...balance sheets...and consequently provided little information” on the assets that should be covered by balance sheet accounts. Although the 1968 SNA “included in principle natural assets in its asset boundary,” it did not do so in a “systematic manner” (Commission of the European Communities *et al.*, 1993; p. 532). This lack of systematic guidance explains, in part, why natural resource assets have not been included in national balance sheet accounts in the past.

The SNA93 has corrected this weakness by providing explicit guidance as to the natural resource assets that should be included in balance sheet accounts and how these assets should be valued. The conditions under which resources are rightly considered economic assets and, therefore, included on balance sheet accounts are clearly stated:

> Naturally occurring assets over which ownership rights have been established and are effectively enforced...qualify as economic assets and [are to] be recorded in balance sheets. [Such assets] do not necessarily have to be owned by individual units, and may be owned collectively by groups of units or by governments on behalf of entire communities...In order to comply with the general definition of an economic asset, natural assets must not only be owned but be capable of bringing economic benefits to their owners, given the technology, scientific knowledge, economic infrastructure, available resources and set of relative prices prevailing on the dates to which the balance sheet relates or expected in the near future (*op. cit.*; p. 219).

The SNA93 recognizes four broad categories of natural resources (formally, “tangible non-produced assets”) that generally meet the above criteria: land, subsoil assets, “non-cultivated biological resources” (timber and wildlife) and water.

Statistics Canada, along with statistical offices in many other nations, is complying with the SNA93’s recommendations respecting natural resources and balance sheet accounts. Beginning in 1997, estimates of natural resource asset values for subsoil assets (fossil fuels, metals, and potash) and timber will be included in the Canadian National Balance Sheet Accounts. At a later date, the estimates of land value already included on the balance sheet will be improved and extended to include other types of land (forest-

1. Previous editions of the SNA guidelines were dated 1953 (United Nations, 1952) and 1968 (United Nations, 1968). International interest in coordinating the economic accounting of nations began much earlier however, dating back to at least 1928.
2. A related indicator, national net worth, is defined as national wealth less net financial claims by non-residents on the domestic sectors of the economy. Financial assets and liabilities of the domestic sectors do not factor into net national worth, as the financial claims of one domestic sector against another cancel out in the summation of assets and liabilities for the economy as a whole.
3. Historically, land has been the only resource included in national balance sheet accounts. In Canada, the value of agricultural land and land under residential and commercial buildings has been included in the Canadian National Balance Sheet Accounts since their inception.

land and parkland for example). Biological resources (other than timber) and water will also be included on the balance sheet in the future, once suitable data sources and valuation methods are found.

The conceptual and empirical issues surrounding the valuation of Canada's natural resource stocks and the inclusion of these values on the national balance sheet are discussed in detail in Chapter 3 of this volume.

System for Integrated Environmental and Economic Accounting

The second set of environment-related guidelines in the SNA93 concerns the development of a "satellite system for integrated environmental and economic accounting" (*op. cit.*; Chapter XXI).[1] A full description of this very elaborate system (which is referred to by the acronym "SEEA") is beyond the scope of the present work. Its major objectives can be noted briefly however.

- The first major objective of the SEEA is reorganization of the standard SNA framework to better serve environmental analysis. One purpose of this reorganization is to make explicit the expenditures on environmental protection activities that prevent and mitigate environmental deterioration or restore the environment. A second purpose is to present in detail the values of natural resource asset stocks and the annual changes in the volume of these stocks (United Nations, 1993; p. 26). The latter is closely related to the SNA93's recommendation to include natural resource asset values in national balance sheet accounts.
- The SEEA's second major objective is the description of the interaction between the economy and the environment in physical terms. There is a strong emphasis in this component on the use of input-output accounting techniques to link physical data on resource use and waste production to economic data from the standard national accounts.
- The final major objective of the SEEA is the calculation of an environmentally-adjusted measure of Net Domestic Product. This is essentially the traditional Net Domestic Product aggregate of the national accounts adjusted for depletion of natural resources and degradation of the environment.

As will be seen in Section 1.2, the System of Environmental and Resource Accounts developed by Statistics Canada bears many similarities to the SEEA. The major difference is found in the SEEA's call for the calculation of an environmentally-adjusted net domestic product. Statistics Canada will not–at least not in the initial conception of the CSERA–redefine or supplement existing national accounts aggregates such as Gross or Net Domestic Product. Nevertheless, the CSERA will provide much of the information necessary for those who may wish to calculate such "green aggregates." On this subject, Statistics Canada's view is that it will take further data development, research and professional discussion before credible aggregates of this kind are possible.[2]

1. In fact, the SNA93 discussion of satellite environmental and resource accounting is a summary of a more complete United Nations handbook on integrated environmental and economic accounting (United Nations, 1993).

1.2 Overview of the CSERA

1.2.1 Natural Resource Stock Accounts

The **Natural Resource Stock Accounts** (NRSA) (columns D and E in Figure 1.1) present annual monetary and physical estimates for stocks of the following natural resources:

- subsoil assets;
- timber; and
- land.[3]

The time series of statistics presented in the NRSA varies depending upon the resource in question and whether the accounts are presented in physical or monetary units. Many of the physical accounts begin in 1961; time series of value estimates generally begin in the mid-1970s.

The geographic scope of the NRSA is, in the main, national and provincial/territorial. The one exception to this rule is the Land Account, which presents data for additional, more detailed spatial units.

As mentioned above, when measured in value terms, the NRSA represent an addition to the existing Canadian National Balance Sheet Accounts (column C in Figure 1.1). This addition of natural resource assets to the balance sheet recognizes the fact that these resources, although provided freely by nature, contribute significantly to Canada's income-generating potential; that is, they are a form of capital that represents an important part of our national wealth. As discussed in Section 1.1, this recognition of natural resource assets as wealth is in accord with the recommendations of the SNA93.

Each of the components of the NRSA is described in more detail below.

Subsoil Asset Accounts

The **Subsoil Asset Accounts** record annual physical and monetary estimates for Canada's "economically recoverable" reserves of:

- crude oil;
- natural gas and its by-products (natural gas liquids and sulphur);

2. For a similar view, see Australian Bureau of Statistics (1993).
3. As described below, other natural resources have yet to be included in the NRSA.

- crude bitumen (or tar sands);
- lignite, subbituminous and bituminous coal;
- metals (copper, nickel, zinc, lead, gold, silver, molybdenum, iron and uranium); and
- potash.

Economically recoverable reserves are those that can be recovered under current technological and economic conditions. They are known with sufficient certainty to be considered economic assets in the SNA93 sense (see page 4) and, therefore, qualify for inclusion in the National Balance Sheet Accounts.

Beyond economically recoverable reserves, the Subsoil Asset Accounts also show supplementary, point-in-time physical estimates for Canada's total resource base. Currently, these estimates are limited to energy resources for the year 1992.[1] They supplement the estimates of economically recoverable reserves with judgments of reserves thought to be recoverable but not yet proven to exist. This broader physical assessment of reserves is included because the annual physical and monetary accounts measure only a (sometimes very small) fraction of total reserves. The estimates of the total resource base present a more complete picture of the resources available to Canada in the long run (Born, 1997).

The Subsoil Asset Accounts take the form of reconciliation accounts. That is, they show estimates for opening and closing stocks in each year plus the volume changes that occurred during the year. Volume changes resulting from new discoveries, reserve development, changes in extraction technology, revisions in reserve estimates, and extraction are recorded in both the physical and monetary accounts. The monetary accounts also include estimates of changes in stock volumes resulting from revaluations caused by changes in resource prices.

In the case of metal resources, the resource classification used in the physical account is distinct from that used in the monetary account. While the physical accounts record reserve quantities for each of the metals listed above, the monetary accounts record reserve values by mine type. The classification of mine types used in the monetary accounts is identical to the classification of mining industries in the *Standard Industrial Classification* (Statistics Canada, 1980):

- gold;
- copper and copper-zinc;
- nickel-copper;
- silver-lead-zinc;
- molybdenum;
- uranium; and
- iron.

Classification by mine type rather than metal in the monetary accounts precludes arbitrary decisions regarding the share of mine development and exploitation costs attributable to each metal in polymetallic mines.[2]

Timber Asset Accounts

The **Timber Asset Accounts** comprise two accounts, one physical and the other monetary, describing Canada's forest resources. The accounts currently focus on the use of the forest for timber supply only. Other uses of the forest–for recreation or wildlife habitat for example–have not yet been considered. Timber supply has been chosen as the initial orientation of the account since this is the principal economic use of the forest in Canada.[3]

In Canada, timber productivity and accessibility limit the portion of the forest that provides economic benefit; that is, they limit the portion that can be considered an economic asset. For this reason, only Canada's accessible, timber-productive, nonreserved forestland is represented in the Timber Asset Accounts. This is the part of Canada's forestland where commercial timber production is viable. The remainder is:

- muskeg, rock, barrens, marshes or meadows within the forestland area;
- other lands that are incapable of producing merchantable timber stands within a reasonable length of time;
- forestland that is presently not stocked with trees; or
- forestland that is reserved for uses other than timber production (parks for example).

Like the Subsoil Asset Accounts, the **Physical Timber Asset Account** is presented as a reconciliation account. It provides annual opening and closing estimates of standing timber stocks and timber-productive land area, plus the changes in the volume of these stocks due to harvesting and natural events. The **Monetary Timber Asset Account**, in contrast, presents only annual value estimates for standing timber stocks. It does not currently include value estimates corresponding to the annual volume changes shown in the physical account. Estimating the value of each component of the annual change in physical timber stocks is not possible given current data sources and valuation methods.

1. The total resource base estimates for energy are very large and are subject to a high degree of uncertainty. For this reason, they are not updated each year, but are presented as "snapshot" estimates instead. The data required to show similar estimates for assets other than energy resources do not exist at this time.
2. A polymetallic mine is one at which more than one metal is mined.
3. Extension of the Timber Asset Accounts to include physical and monetary statistics for forestland uses other than timber production will be undertaken in the future. Estimates of stocks and values of parkland will be a primary focus of this development.

Both the physical and monetary timber asset accounts present time series beginning in 1961 at the national and provincial/territorial levels.[1]

The Physical Timber Asset Account is based on forest resource inventories produced by provincial and territorial forest departments/ministries. These inventories often use different land bases from one period to the next. As a result, consistent timber stock data are not available as an annual time series in Canada. To overcome this lack of data, the stock/flow time series of the Physical Timber Asset Account is estimated using a simulation model. Beginning with data from *Canada's Forest Inventory 1991* (Lowe, Power and Gray, 1994), this model simulates the impact of growth, harvesting, natural loss and other changes to timber stocks. The model generates the required time series of physical stock estimates for Canada's timber-productive forestland, beginning in 1961.

The Monetary Timber Asset Account presents annual value estimates of the standing timber on Canada's timber-productive forestland. These estimates are based on the present value of an assumed stream of future income (or resource rent) realizable from the exploitation of timber resources. Following the recommendations of the SNA93, the timber value estimates calculated in the Monetary Timber Asset Account are included in the National Balance Sheet Accounts as part of Canada's natural resource wealth.

Land Account

Until now, information on Canada's land resources has been scarce at the national level. Moreover, the available information has often been outdated and highly generalized. The **Land Account** component of the NRSA provides improved information to describe this resource.

Although not harvestable like subsoil assets or timber, land is a key input into many economic activities. A number of unique attributes set land apart from these other resources however. To begin with, the total stock of land in Canada is fixed for all intents and purposes. Thus, a reduction in the stock of one type of land (agricultural land perhaps) requires an equivalent, offsetting increase in the stock of another type of land (urban land for example). Land potential, in terms of its usefulness in particular applications, also varies tremendously from one location to another. Land suitability for farming, for example, can differ from field to field. The use to which a particular parcel of land is put thus depends very much on where it is located.

Given the unique attributes of land, the Land Account itself differs in a number of ways from the two components of the NRSA just described.

To begin with, the Land Account is not represented as an *annual* time series of stock estimates. Although certain characteristics of land (such as vegetative cover) can and do change over time, significant changes do not usually occur over the span of a single year. They take place instead over several years or even decades. For this reason, the Land Account is not represented as an *annual* time series of stock estimates, but is updated on a multi-year cycle instead. Some components of the account are updated every two to three years (land cover for example); major revisions are made every five years following the release of new information from the censuses of population and agriculture.

The Land Account further differs from the subsoil and timber asset accounts in that it is not represented as a series of provincial and national reconciliation accounts. Reconciliation accounts are suitable only for resources that are depletable; that is, resources for which the total stock can be reduced (or augmented) from one period to the next. This is not the case for land. As noted above, for all intents and purposes, the total stock of land in Canada is fixed and a reduction in one type of land implies an increase in another type. Thus, changes in land stocks are best represented in a two-dimensional transition matrix showing the flows between stock categories. At this time, the data required to develop such a transition matrix for land are not available in Canada. The Land Account thus presents only beginning-of-period stock estimates by land category, without showing the flows that contribute to the changes in these stocks during each period.

The final distinctive feature of the Land Account is its use of a detailed spatial framework. Whereas the other resource stock accounts are compiled only at the national and provincial/ territorial levels, the importance of location in determining the characteristics of land resources demands that the Land Account be compiled using much smaller spatial units. The spatial framework used in the Land Account is formed from the amalgamation of ecological, political and statistical regions.

Given the above considerations, the Land Account is conceived as a large, spatially-referenced database of land statistics compiled into five layers.

- A spatial framework forms the **physical foundation**, and first layer, of the Land Account. This foundation provides the structure for the remaining four layers of the account. The foundation is constructed from the union of a detailed digital map of provincial/territorial boundaries with digital maps of ecological units known as ecoregions and statistical regions known as census enumeration areas. The union of these three elements into a single spatial framework for the Land Account, comprising over 5600 separate units, is accomplished using Geographic Information System technology.
- A **land cover** layer describes the physical nature of land for each spatial unit defined in the physical foundation. The land-cover classes employed in the account are coniferous, broadleaved or mixed/ transitional forest; tundra; sparsely vegetated or barren land; cropland, rangeland and pasture; perennial snow and ice; built-up area; open water and sea ice.

1. The Physical Timber Asset Account currently excludes Prince Edward Island, Manitoba and the Northwest Territories. A lack of suitable data for these regions precludes their inclusion in the account.

- A **land use** layer describes how land in each spatial unit is used for business activities, non-commercial human activities and ecological purposes. The land-use classes employed in the account are urban, rural, agricultural, forest, transportation, utilities and “other”.
- A **land potential** layer describes the biophysical properties of the land in each spatial unit in terms of climate, geology, topography and soil characteristics. Land potential is determined by characteristics that are, for all intents and purposes, fixed over time. Thus, this layer of the account is not updated each decade.
- Finally a **land value** layer presents estimates of land value by spatial unit. The Land Account extends the land value estimates (for agricultural, residential and commercial land) that are already included in the National Balance Sheet Accounts.[1] This includes estimating values for forestland and parkland, and improving the existing estimates for agricultural land. Along with estimates of land values in market uses, the Land Account also includes measures of non-market direct-use values, indirect-use values, and non human-use values.

As with the other resource stock accounts, the time series of data presented in the Land Account varies significantly depending upon the land resource category in question. Thanks to Statistics Canada’s long-standing program of collecting agricultural statistics, estimates of agricultural land use are available back to 1901. Estimates of land used for other purposes begin in 1971. Detailed estimates of land cover for the entire country currently exist only for 1991.

Other resources

The development of stock accounts for other natural resources has not progressed as far as that for subsoil assets, timber and land. This is mainly due to a lack of suitable data. In particular, although considerable effort has been devoted to investigating the data sources for a physical account of marine resource stocks, this effort has met with relatively little success. Pelagic (or finned) fish and shellfish stocks are estimated by officials only when there appears to be a problem with a localized fishery, and then only for the species of concern. Thus, there exist no annual estimates of stock by species for each fishery in the country and, therefore, no data from which an aggregate fish stock account could be compiled (Austin, 1996).

The situation is somewhat better for terrestrial animals that are of importance as game or for fur production. Population data of the sort that could be used to develop a stock account are often estimated for game species on the basis of reported hunting successes. Likewise, stocks of fur-bearing animals are estimated on the basis of number of pelts harvested in a season. The use of these data to develop stock accounts for wildlife species is still being investigated.

1. The land value layer of the Land Account currently exists in concept only; data development is still at the pilot stage. Eventually, the market-based land value estimates from the Land Account will be incorporated into the National Balance Sheet Accounts. These estimates will therefore be updated on an annual basis.

1.2.2 Material and Energy Flow Accounts

Flows of produced goods and services are well articulated in monetary terms in the existing national accounts. The Input-Output Accounts (cells 2A, 3A, 3B and 3C of Figure 1.1) provide annual estimates of the production and consumption of 485 commodities by 161 industries and 136 categories of final demand. The **Material and Energy Flow Accounts** (MEFA) build on this substantial detail by incorporating physical estimates of natural resource and waste flows into the accounting framework of the Input-Output Accounts.

The MEFA (cells 5A, 5B, 6A and 6B in Figure 1.1) record in detail the annual flows of materials and energy–in the form of natural resources and wastes–between the Canadian economy and the environment. Estimates are made for each of the 161 industries represented in the Input-Output Accounts, and for an array of household and government activities. The accounts record the quantities of natural resources produced (that is, harvested or extracted) by industries, households and governments, and show how these resources are consumed by these same agents. Likewise for wastes, the accounts show the quantities produced by each agent and how these wastes are “consumed,” either as recycled materials or as flows into waste disposal sites or to the environment.

The MEFA represent a unique source of environmental information, never before available in Canada. Although some of the basic data that they present are available elsewhere, these data are typically dispersed among many organizations and are often difficult to access. The MEFA represent the first effort to bring these resource and waste data together as a single, consistently organized and comprehensive set. More importantly, they represent the first time that detailed data on resource and waste flows have been directly linked with Statistics Canada’s economic statistics. It is this linkage that provides the analytical strength of the accounts.

As noted, the MEFA measure the flows of natural resources and wastes associated with the activities of industries, households and governments. By linking these physical measures with data from the Input-Output Accounts, detailed estimates of the resource and waste intensity of economic activities are produced. These intensities measure the physical quantities of resources (or wastes) used (or produced) per unit of economic activity. For example, tonnes of carbon dioxide emitted per thousand dollars of electricity production. Such measures provide indicators of the burden placed on the environment by economic activities.

In principle, the MEFA record *all* resource and waste flows between the economy and the environment. In practice, it is neither possible nor desirable that the accounts be this complete. Some material and energy flows are of little interest from an environmental perspective and are therefore excluded from the accounts. Materials that are nearly unlimited in supply–air for example–are one such case. More often it is the case that a particular flow is rightly included in the accounts, but that the data necessary to do so are unavailable. Indeed, data currently available in Canada represent only a fraction of the flows that ideally would be measured in the MEFA (although the flows that are measured are among the most important). As expanded data on material and energy flows are developed, the range of materials and energy measured in the account will grow.

Given their close relationship with the Input-Output Accounts, many of the characteristics of the MEFA are determined by the need for comparability with the former. For example, as already mentioned, the MEFA are compiled using the sectoral classifications of the Input-Output Accounts. Likewise, the geographical scope of the MEFA is national and the frequency with which they are compiled is annual, matching the scope and frequency of Input-Output Accounts. One drawback of this close relationship is the fact that the very detailed Input-Output Accounts require a long compilation period. The accounts are only published four years after the reference year as a result. The MEFA are thus somewhat restricted in their ability to provide current analysis of material and energy flows.[1]

To date, the empirical development of the MEFA has focused on accounts for greenhouse gas emissions plus the following natural resources:

- energy;
- water;
- pelagic (finned) fish and shellfish; and
- agricultural products.

The time series of data presented in the MEFA vary according to the flow in question. Several of the series begin in 1981 (energy, water, greenhouse gases).[2] Data for marine resource flows commence in 1961. Agricultural product flows are available from 1951 onward.

1.2.3 Environmental Protection Expenditure Accounts

The impacts of economic activity on the environment have become a matter of increasing public concern in recent decades. In response, businesses, households and governments alike have spent substantial sums of money on environmental protection. The **Environmental Protection Expenditure Accounts** (EPEA; row 4 in Figure 1.1) decompose the framework of the existing national accounts to show the extent and distribution of these expenditures. Such information is of interest for several reasons.

- Environmental protection expenditures are one measure of society's response to the negative environmental effects of economic activity.
- By definition, environmental protection expenditures yield no immediate *economic* benefits. Consequently, it is useful to distinguish them from other expenditures when analysing economic growth.
- Environmental protection expenditures impose a financial burden on the economy that can be measured and, to the extent possible, compared to the benefits gained in terms of a lessening of the impact of economic activity on the environment.
- Environmental protection expenditures show, from a demand-side perspective, the contribution of environmental protection activities to Canada's economy. Considered another way, they represent the size and characteristics of the Canadian demand for goods and services produced for environmental protection purposes.

Some would argue that expenditures on environmental protection represent part of the cost of maintaining natural capital and that, as such, they should be excluded from the value of production measured in the national accounts. Although Statistics Canada has no current plans to modify Gross or Net Domestic Product in this way (as was noted earlier), the EPEA provide those who might be interested in calculating such environmentally-adjusted aggregates with information necessary to do so.

The EPEA present an annual time-series of current and capital expenditures on environmental protection. The EPEA comprise three accounts, one for each sector of the economy:

- household expenditures on environmental protection;
- government current and capital expenditures on environmental protection, plus intergovernmental and intersectoral government transfer payments; and
- business capital and operating expenditures on environmental protection.

Where possible, capital expenditures are distinguished from current expenditures, and transfer payments are reported separately from other expenditures.

A major challenge in the development of the EPEA has been arriving at a practicable definition of "environmental protection expenditures." The difficulty here lies in attributing an explicit environmental protection purpose to expenditures. This is not straightforward in many cases, as a number of factors are normally at play in motivating a given expenditure. Take an investment in fuel-efficient equipment for example. Although such an investment could theoreti-

1. This said, it should be noted that Statistics Canada is currently working toward producing much more timely Input-Output Accounts at both the national and provincial/territorial levels.
2. The time series for water currently includes 1981, 1986 and 1991 only.

cally be motivated entirely for reasons of environmental protection, this seems unlikely. Most often an economic consideration would be present as at least a secondary, if not primary, motivation. Investments with environmental benefits that are motivated in part or in whole for economic reasons are problematic in an environmental protection account. Are they, or are they not, environmental protection expenditures?

The difficulty presented by multi-purpose expenditures is dealt with in the EPEA by defining environmental protection expenditures as those undertaken for the purpose of complying with environmental regulations and/or conventions.[1] Environmental regulations/conventions make explicit what normally would be implicit. Even if there is a financial advantage to a company in adopting a new technology that contributes to environmental protection, the fact that its adoption is undertaken for the sake of regulatory compliance ensures that there is an overriding environmental motivation.

Prior to the development of the EPEA, little information on business sector environmental protection expenditures existed in Canada. In order to overcome this problem, a new business survey has been designed and implemented with the explicit objective of collecting environmental protection expenditure data. Results from this new survey are combined with those from an existing Statistics Canada survey to form the basis for the business sector component of the EPEA. Estimates currently begin with the year 1985 for this sector.

Despite many challenges faced in adapting government expenditure data for use in the EPEA, a lengthy time series of environmental protection expenditure estimates for this sector has been compiled. Total government expenditures are available beginning with the fiscal year 1970/71. Information on the split between current and capital expenditures is available on a calendar-year basis beginning in 1985.

Data sources and methods for the household sector have yet to be thoroughly investigated for the EPEA. Measured expenditures will be limited to the costs associated with pollution and noise control devices on automobiles, plus expenditures on solid waste and sewage treatment not supplied by governments.

1.3 Sustainable development and the CSERA

Many of the concerns related to resource depletion and environmental degradation are reflected in the concept of sustainable development. In its most widely accepted formulation, that of the aforementioned Brundtland Commission, sustainable development is defined as:

> development that meets the needs of the present without compromising the ability of future generations to meet their own needs (World Commission on Environment and Development, 1987; p. 8).

The Brundtland Commission left its definition intentionally vague so that the concept of sustainable development would not be confined to any particular category of needs. In the period since the Commission's report, a consensus has emerged that sustainable development refers at once to economic, social and environmental needs. A clear social objective that falls out of the definition is that of equity, both among members of the present generation and between the present and future generations. Exactly what it is that is to be shared equitably among and between generations is obviously a subjective and controversial matter, but it is clear that the spirit of sustainable development implies that all people have the right to a healthy, productive environment and the economic and social benefits that come with it.

While the Brundtland definition is attractive for its simplicity and the wide appeal of its message, it offers little in the way of a measurable objective for sustainable development. Thus, economists, among many other groups, have attempted to operationalize the concept with the goal of understanding its implications for current and future economic development.

The economist's view of sustainability

Although one finds a predictable amount of disagreement among economists as to the economic interpretation of sustainable development, substantial agreement exists on one point: sustainable development is closely related to the long-standing economic concept of income. Most economists refer back to Hicks' (1946) definition of income in this regard:

> income is the maximum amount an individual can consume during a period and remain as well off at the end of the period as at the beginning.

The Hicksian concept of income is easily explained with a simple example. Imagine an individual whose only source of income is a stock portfolio valued at $1 million at the beginning of a year. This is a well-managed portfolio, paying its owner a net return of 15% annually. The investor's annual **income** in this case is $150 thousand, as this is the maximum amount that she can consume in a year without depleting her capital investment (that is, her stock portfolio).

Although there are obvious and important differences between the economic affairs of an individual and those of an entire nation, the above definition of income applies equally well to both. The income of a nation can thus be defined as the amount that it can collectively spend during a period

1. Environmental conventions include any formal multi-party commitment to meet specific targets relating to environmental protection. In contrast to regulations, for which compliance is required by statute, compliance to conventions is normally voluntary.

without depleting the capital base (or wealth) upon which it relies to generate this income.

As noted, the concept of income has a long-standing place in economic theory. The advent of sustainable development has, however, altered the way in which many economists think about national income and its relationship to national wealth. In the past, economists tended to focus on "produced" capital (that is, buildings, machinery and other human-made factors of production) as the basis of economic wealth and, therefore, the source of income. Now, with the emphasis of sustainable development on the preservation of the productive capacity of the environment, many economists argue that the contribution of a nation's **natural wealth** (or natural capital) to income cannot be ignored in discussions of national income and wealth.[1] This has lead to the following widely accepted economic interpretation of sustainable development:

> Economically sustainable development is development that generates non-declining *per capita* national income by replacing or conserving the sources of that income; that is, the stocks of produced and natural capital (Bartelmus, 1990).

As discussed further below, it is this interpretation of sustainable development that is embodied in Statistics Canada's environmental and resource accounts.

It is important to point out here that the concept of natural capital implicit in the economic interpretation of sustainable development encompasses more than just stocks of natural resources. Economic activity and human well-being also depend on the environment for a large number of environmental services and amenities, such as the dispersion and assimilation of wastes and the production of oxygen. The flow of these services is analogous to the flow of services provided by produced capital goods. Thus, the environmental systems that provide these services must be seen to represent natural capital in the same way that timber or mineral stocks do.

Even if many economists accept the basic idea that sustainable development requires consideration of both produced and natural capital, the relationship between the two is still the subject of much debate. In particular, the extent to which produced capital can act as a substitute for natural capital remains controversial. Many economists argue that produced capital is very often, if not always, a substitute for natural capital. Humankind has, they note by way of example, employed produced capital to devise chemical fertilizers that substitute for the natural fertility of soil. Even soil itself can be replaced in a limited way through the use of hydroponics. Others argue, in contrast, that some forms of natural capital exist for which there are no current or foreseeable produced substitutes; the ozone layer is one important example. Some economists would even argue that all produced capital is ultimately derived from natural capital and, therefore, there is never any real substitution of the former for the latter.

Text Box 1.1

Sustainable development continuum

In order to operationalize the concept of sustainable development, many economists interpret it as the need to maintain stocks of produced and natural capital (Daly and Cobb; 1989; Pearce *et al.*, 1989; Pearce and Turner, 1990; Victor, 1991; El Serafy, 1996). Although all agree that both natural and produced capital are important when considering sustainability, there is a divergence of opinion as to whether the two forms of capital are complements or substitutes. This divergence has lead to the development of two opposing interpretations of economic sustainability.

- *Weak sustainability* seeks to maintain from year-to-year the *per capita* income generated from the **total** capital stock (produced and natural) available to a nation. No regard is given to the composition of this stock, as it is assumed that produced and natural capital are substitutes for one another. Thus, only the total value of capital need remain intact for income to be non-declining. Weak sustainability clearly allows for the depletion or degradation of natural resources, so long as such depletion is offset by increases in the stock of produced capital (for example, by investing royalties from depleting mineral reserves in factories).
- *Strong sustainability* requires that both natural capital and produced capital be maintained intact independent of one another. The assumption implicit in this interpretation of sustainability is that the two forms of capital are mainly complementary; that is, one is generally necessary for the other to be of any value. Produced capital used in harvesting and processing timber, for example, is of no value in the absence of stocks of timber to harvest. Only by maintaining both natural and produced capital stocks intact, the proponents of strong sustainability argue, can non-declining income be assured.

Regardless of which of the two interpretations one accepts, the effect of an increasing population is the same. Not only must capital stocks be non-diminishing, they must in fact grow at the same rate as the population if *per capita* income is to remain constant.

Strong and weak sustainability

The controversy over the degree of substitutability of produced capital for natural capital has translated into a continuum of economic interpretations of sustainable development. At opposite ends of this spectrum are what

1. However, as the quote from Scott on page 2 clearly demonstrates, a few economists have recognized all along that natural capital is just as important as produced capital in this regard.

are known as *weak* and *strong* sustainability (Text Box 1.1). Regardless of which of these economic interpretations one accepts, the same basic tenet is apparent: use of the environment must be compatible with long-term maintenance of capital stocks. Although this principle is inherent in both the strong and weak definitions of economic sustainability, its implications differ depending upon which interpretation one accepts.

Under a regime of weak sustainability, natural resource stocks may be depleted, and environmental systems degraded, but only if this depletion/degradation is offset by equivalent or greater increases in the stocks of produced capital. That is, so long as there is no reduction in total capital stocks *per capita* (produced and natural), the economy is assumed to be operating sustainably. Since it is the total value of capital stocks that is to be maintained, both natural and produced capital must be measured using the same yardstick. Thus, weak sustainability implies measurement of natural capital stocks in monetary terms, as produced capital is normally measured using dollars as the yardstick.

Strong sustainability sets more strict rules for the use of the environment. Renewable natural resources (such as forests) may be used, but only at the rate at which they naturally regenerate. That is, depletion of renewable resource stocks is not allowed. Non-renewable resources may also be used, but only at the rate at which renewable substitutes can be produced.[1] Non-renewable resources for which no substitutes exist are to be used minimally (if at all), and maximum recycling of these resources is required. Environmental systems are, in general, not to be degraded. In the limited instances where produced substitutes are available for these systems, degradation is allowed, but only to the extent that the produced capital flows offset the lost natural capital services. Environmental systems that provide irreplaceable services (such as the ozone layer) are not to be degraded at all.

Strong sustainability requires that stocks of natural and produced capital be maintained intact independent of one another. There is, therefore, no reason why the two forms of capital must be measured using the same units of measure. This allows for measurement of natural capital stocks in physical, rather than monetary, units. This is often straightforward. Stocks of many natural resources can be measured using simple physical units and readily available stock data (subsoil and timber assets are generally of this nature). Measuring the natural capital represented by environmental systems–the waste assimilation capacity of a river system for example–is much more difficult. Indeed, no efforts have yet been made in the CSERA to measure stocks of this form of natural capital.

1. For example, the depletion of fossil fuels could occur at a rate no greater than the rate at which renewable alternatives (wood methanol perhaps) can be produced.

Implications for the CSERA

The CSERA has been conceived, at least in part, as a tool for measuring progress toward economic sustainability.[2] The system has not been designed to reflect any particular economic interpretation of sustainable development, but instead to offer information that is useful for addressing many possible interpretations. Questions of the sort listed below can be addressed through the CSERA.

- Are stocks of natural capital, in both value and physical terms, being maintained in Canada?
- Is the consumption of renewable natural resources within the capacity of the environment to regenerate these resources, or are stocks of these resources declining?
- Are discoveries of new subsoil assets maintaining pace with our depletion of existing assets? What is the total subsoil resource base in Canada, including discovered and (estimated) undiscovered resources?
- What are the flows of waste materials associated with economic activity? Who produces these flows (industries, households or governments)? Are these flows on the increase or decrease, both in total and per unit of economic activity?
- How much of our waste do we recycle? What share of our material input needs are met by recycled materials?
- What are the patterns of land use in Canada? How are these changing? Are stocks of important land types, high quality agricultural land for example, being maintained?
- How much is spent to protect the environment? Who makes these expenditures? Are they increasing or decreasing and why?

1.4 Future directions for the CSERA

A great deal of effort has been put into filling the framework of the CSERA with high-quality statistics. As a result, many more questions about the interaction between the economy and environment can be answered today than even a few years ago. Of course, the system cannot claim to provide definitive and/or complete answers to all such questions. As noted in the preface to this volume, the CSERA remains a work-in-progress that will continue to develop with time. In this regard, several conceptual issues and data shortcom-

2. Although aspects of sustainability other than those relevant to the economic interpretations presented here are recognized to be important, they are not currently dealt with in the CSERA.

ings to be given priority in future development of the system are summarized below.[1]

Natural Resource Stock Accounts

Priority for the future expansion of the NRSA will be placed on the development of physical and monetary stock estimates for land areas that offer environmental services rather than raw materials; recreational and wilderness areas for example. This work will commence with the development of physical stock accounts for parkland and progress toward the estimation of values for this and similar land areas. The ultimate goal is an estimate of the value of Canada's natural capital in terms of both the raw materials that it provides and the services that it offers.

The development of accounts for resources for which quality is equally important as quantity will also be undertaken in the future. Water is the most obvious candidate for this type of account. A straightforward physical account of water stocks would be of questionable value in Canada, given the enormous quantities of water with which we are endowed. A stock account for water incorporating qualitative dimensions, such as suitability and availability of water for human consumption, would be very useful however.

Despite the progress that has been made to date with respect to the valuation of natural capital, much work remains in this area. The convergence of international opinion that is emerging on the favoured methods for valuing stocks of economic resources, such as timber and sub-soil assets, is far off in the case of other resources. Valuation methods for resources for which there are multiple, concurrent uses (such as forests) are not well developed at this time.

Material and Energy Flow Accounts

Although the conceptual framework of the MEFA is well-established, their current state of empirical development represents only a small fraction of the material and energy flows that would be ideally covered. With respect to waste flows, estimates of greenhouse gas emissions are the sole statistics to have been compiled to date. Although a number of sources of data on other waste flows do exist and have been investigated, substantial future effort remains before these can be incorporated into the MEFA framework. Important wastes for which data sources are problematic, or do not exist at all, include: solid wastes, sewage and other water-borne wastes, ozone-depleting substances, acid-rain causing gases, volatile organic compounds, heavy metals and other hazardous wastes. A promising source of waste data that will be a primary focus of future investigation is Environment Canada's *National Pollutant Release Inventory*.

With respect to natural resource flows, current plans call for the development of estimates for timber, metallic and non-metallic minerals and possibly land. Statistics Canada collects many of the raw data required to incorporate these flows into the MEFA framework. Integrating these data is a high priority for the future development of the MEFA. Estimating the quantities of recycled wastes that are used in place of virgin resources is also a high priority.

An interesting methodological challenge to be faced in the MEFA is the development of techniques for summing disparate material flows into meaningful aggregate measures. This is already possible for greenhouse gases and several other categories of wastes (Puolamaa *et al.*, 1996). The extent to which similar methods can be developed for other categories of wastes and/or natural resources remains to be seen.

Environmental Protection Expenditure Accounts

Much of the future development of the EPEA will be focused on the consolidation of data from existing sources and, to a lesser extent, on the development of new data sources. As noted earlier, no estimates of environmental protection expenditures have yet been made for households; this is an obvious priority for future work.

Beyond expanding the estimates of environmental protection expenditures, an important future objective is the measurement of environmental protection from the supply side of the economy. Survey work currently under way, or planned, will provide the data necessary for the development of an integrated demand-supply environmental protection expenditure account in the future. The use of the input-output accounting framework as the basis for this account will be investigated.

Another longer-term objective for the EPEA is linkage of environmental protection expenditure data with data on waste output from the MEFA. The effectiveness of environmental protection expenditures in terms of reduced waste emissions would, in theory, be measurable once such a linkage was established.

1. The future directions for each of the components of the CSERA are outlined in more detail in the chapters that follow.

ELECTRONIC PUBLICATIONS AVAILABLE AT

www.statcan.ca

2 International Comparisons

Canada is one of a number of countries leading the development of environmental and resource accounting. Although the direction followed in individual countries tends to be influenced by domestic resource endowments and environmental and political concerns, there are common concerns that transcend national borders. This fact points to the need for internationally-comparable accounting frameworks.

A number of organisations are working to ensure international comparability in environmental and resource accounts through the promotion of standard methods and concepts. One such organisation is the so-called *London Group on Resource and Environmental Accounting*, an informal group of approximately 30 statisticians representing 14 countries and 5 international organisations. Statisticians active in the development of environmental and resource accounts convene annually to discuss progress and exchange ideas relevant to the conceptual and practical considerations of the field.[1]

This chapter provides an overview of the accounting structures used by a sample of the *London Group* member countries.

2.1 Norway

Among the members of the *London Group*, Norway has the longest experience with environmental and resource accounting. Understanding the evolution of Norway's accounts provides important insight into their current composition.

In the mid 1970s, in response to increasing conflicts between conservationists and politicians, Norway embarked on a program to develop environmental and resource accounts. The primary objective was the provision of information that would improve the management of natural resources. During the period 1978 to 1986, accounts for energy, fish, land use, forest and minerals were developed. The approach initially taken by Norway separated natural resources into two broad classes: material and environmental. Material resources were further subdivided into mineral resources, biotic resources and inflowing resources.

Mineral resources were straightforwardly defined as non-living, non-renewable resources, and included crude oil, natural gas, coal, metals, minerals and other non-renewable materials. Biotic (living) resources covered forests and fish and were defined as conditionally or potentially renewable. Inflowing resources were defined as those that, for all intents and purposes, are unconditionally renewable because the volume available makes it virtually impossible to extinguish the stock: solar radiation, ocean currents and the hydrological cycle (water).

Environmental resources were distinguished from material resources by the fact that the former provide services rather than goods. Under the Norwegian definition, environmental resources included air and water in their role as waste disposal media, and land used for recreational purposes. Clearly, these resources can cross the boundary between environmental and material resources. Thus, environmental resources were further distinguished as those for which the quality or state of the resource determines its usefulness.

For each of the accounts and sub-accounts, reserves, extraction, transformation, trade and domestic use were recorded in physical units.

This rich base of information served decision makers well during the periods of crisis precipitated by the resource depletion concerns and oil price shocks of the 1970s and 1980s. The reduced resource use witnessed in the face of price increases during the 1980s attracted the interest of decision makers and prompted a change in the focus of the Norwegian accounts. Decision makers wanted to examine more closely the linkages between the physical resource accounts and economic information in the national accounts.

In the late 1980s and early 1990s, appreciation of the vast effort needed to develop and maintain a comprehensive accounting system in conjunction with the need to expand the scope of the system to show environment-economy linkages led to a narrowing of the focus of account development. A few economically and politically important resource issues–energy resource management in particular–and important environmental issues such as air pollution became the focus. Land-use accounting was discontinued, although forest, fish and mineral accounts were maintained.

A material resource account is still maintained in physical terms for stocks and flows by category of user, all of which follow the sectoral structure and classification systems of the Norwegian SNA. Wherever possible these data are complemented with market price information. This facilitates linkage between the resource accounts and the SNA. Sub-accounts within the material resource account differ with respect to the detail they present. Biotic resource accounts, for example, include elements such as age-structure, geographic location and quality, in addition to the standard measures of reserves presented for all resources. In addition to accounts for material resources like fish, for-

1. The *London Group* meets annually and the papers and proceedings are published by a participating agency on behalf of the group. Copies of the proceedings can be obtained by contacting the agencies directly. The volumes were published as follows: inaugural meeting, London, England (Statistics Canada, 1994); second meeting, Washington, D.C. (U.S. Bureau of Economic Analysis, 1995); third meeting, Stockholm, Sweden (Statistics Sweden, 1996).

ests and energy, related statistical information is collected for environmental resources; namely, air, water and land.

During the 1990s, there has been less focus in Norway on maintaining a comprehensive set of environmental resource stock, flow and use accounts, and on studying resource issues within traditional economic planning systems. These planning systems tended to examine environmental implications of economic activity from an economic perspective only. The revised objective is to secure consistency between economic analysis and analysis of important environmental and resource issues. For example, the energy account has become an important and necessary foundation for emission inventories, which at present cover sectoral emissions of greenhouse gases, particulate matter, volatile organic compounds, lead and nitrogen oxides. The emission data are used in conjunction with economic data to forecast the consequences of economic development and the associated demand for energy.

Recent Norwegian initiatives include a pilot project to estimate waste outputs from selected industries and the assembly of expenditure information on municipal wastewater and solid waste management.

2.2 Finland

The programme of environmental and resource accounting in Finland arose in the mid 1980s from interest in ensuring the sustainable use of forests, the most important natural resource in the Finnish economy. This culminated in the production of stock and flow accounts for timber and fossil fuels, an account of air emissions from fossil fuel combustion and an environmental expenditure account. Linkage of these accounts to standard economic measures is achieved via the industrial classifications of the Finnish SNA. The accounts have been used in economic modelling, in carbon balance accounting and in experimental monetary valuation of forest resources.

The timber material accounts include physical measures of the forest balance (stock, growth, natural losses and harvesting, by wood type), use of the forest, and a wood mass balance that tracks the mass of wood products through the economy from harvesting to final consumption, including associated waste materials. The detailed structure of the accounts is compatible with the SEEA, but reflects primarily an interest in supporting national forest management policy tools. The focus of development has been on physical measures, with limited work devoted to the elaboration of monetary values for the forests.

Physical accounts for energy based on the input-output accounts show the output of the energy industries as inputs to 50 industries and households for 11 fuel commodities. In addition to providing insight into energy efficiency, these accounts are used to model greenhouse gas and particulate emissions from fuel consumption by industry, fuel and region.

Environmental protection expenditures by the mining and energy production industries have been developed following the framework of SEEA. These data will be linked to emissions data as an aid in evaluating the cost-effectiveness of environmental controls.

To date, the Finnish approach to environmental and resource accounting has focused on specific aspects of environmental issues and not on the elaboration of a comprehensive accounting framework. Nevertheless, the approach has lent itself readily to linkage with components of the SNA, resulting in experimental macro-indicators for the environment. Future work will expand the timber material account to address a number of issues: forest quality, health and biodiversity; age and structure of the forests; the impact of logging methods; and the impact of changes in protected forest areas.

2.3 Germany

Germany has chosen to follow the SEEA closely in its approach to environmental and resource accounting. The basic structure for the German accounts addresses five subject fields: material and energy flow accounts; land accounts; evaluation of the state of the environment; environmental protection expenditures; and imputed prevention costs for attaining sustainability standards. The material and energy flow accounts and land accounts are elaborated in physical terms, while the other three accounts employ a combination of physical and monetary measures.

The German initiative disaggregates the conventional economic accounts to identify environment-related “defensive” activities, and introduces natural asset accounts to the conventional German SNA. The material and energy flow accounts are being developed to provide insight into the link between the environment and economic activity. Together, these form an integral part of the satellite environmental accounts.

As an extension of the resource use accounts, an experimental material flow account was formulated as a comprehensive materials balance in a closed system. Physical input-output tables were constructed to allow natural resources to be traced through the economy as inputs, outputs (including foreign trade and accumulation in infrastructure) and residuals. This approach allows the estimation of total waste flows, since all materials entering and leaving the system are reconciled.

Other developments will ultimately lead to expansion of the environmental and resources accounts. Interim objectives include providing input to the state of the environment assessment. Attempts are under way to examine the impact of environmental targets on the economy. Land use and cover will contribute to the natural asset accounts and to the material flow accounts. Environmental costs will help in the derivation of estimates for natural asset depreciation.

2.4 Australia

In addition to a commitment to expand its existing system of national accounts to include the environment under its *Agenda 21* resolution, Australia is also developing environmental and resource accounts in support of its *National Strategy for Ecologically Sustainable Development*. These commitments have taken form initially in the direct introduction of environmental assets to the national and sector balance sheets of the Australian SNA, and in the development of satellite environmental accounts.

Australia follows the direction for satellite account development set out in the SEEA. The accounts developed or planned to date include:

- estimates of the value of natural assets;
- estimates of environmental protection expenditures, by sector and industry on an annual basis;
- stock, flow and waste output accounts in physical units for a range of natural resources, including energy;
- environmental pressure indicators linked with flow data from physical accounts that enable calculation of measures such as sector and industry contributions to issues of environmental concern; and, eventually,
- monetary estimates for environmental degradation and resource depletion.

Market values (or proxies) for stocks of natural assets are being developed for forests, inland water, fisheries, land and subsoil assets. This emphasis reflects Australia's natural resource endowments. Consistent with the rest of the economic accounts, these estimates relate only to economically exploitable assets and exclude non-market services such as biodiversity or clean air.

The standard Australian SNA is also disaggregated to reveal links to natural resource use. One area affected is the national balance sheet (specifically the entry for "other changes in volume of assets"), where depletion, discoveries, growth and degradation of natural assets (within the boundaries of SNA concepts) are now separately identified. The other affected area is the expenditure estimates of the input-output accounts. Expenditures having the specific purpose of protecting or repairing the environment are isolated to allow examination of the cost of environmental protection in the economy.

2.5 Denmark

While there has been no development to date of an integrated framework for environmental and resource accounting in Denmark, a number of relevant projects have been undertaken. These have observed the guidelines of both the SNA93 and the SEEA. Denmark is further proceeding to implement the recommendations of the SNA93 and SEEA with respect to natural resource stock accounts, with a particular focus on crude oil, natural gas, land, forest and fish resources. Estimates in both physical and monetary units are being developed. Notably, the requirements of environmental analysis were considered during development of the new industry classification recently implemented in the Danish SNA.

Since the mid 1970s, Danish input-output tables have been used in conjunction with energy consumption and air emissions data to illustrate–via a materials balance approach–the use of 23 different types of energy in 117 industries and several categories of final demand. Although this work was first undertaken to better understand energy use in response to the oil crisis of the early 1970s, the focus has now turned to the environmental aspects of energy production and use. The introduction of wastes into the materials balance equation reflects this change in emphasis.

As in other countries, components of the Danish input-output tables have also been disaggregated to separately show environmental protection activities.

2.6 The Netherlands

In response to increasing concern about the impact of economic activity on the environment, the Netherlands expanded its SNA framework in the early 1980s to include environmental information. The resulting system is referred to as the *National Accounting Matrix including Environmental Accounts* (NAMEA). The objective of the NAMEA at the most aggregate level is to provide a set of interrelated macro-indicators for the economy and the environment. Three modifications to the standard Dutch SNA were made in order to produce the NAMEA.

First, a new accounting framework was developed to provide summary environmental indicators along national and global environmental themes. The themes, adopted from the Netherlands' *National Environmental Policy Plan*, include the greenhouse effect, depletion of the ozone layer, acidification, eutrophication, waste accumulation, and resource depletion.

Second, production information was expanded to include detailed data on the physical output of waste materials. On the basis of the relative contribution of each waste to each environmental theme, emissions are weighted and summed to produce total emissions by theme. The result is a limited set of summary environmental indicators that are comparable with conventional economic aggregates.

Third, in addition to the introduction of environmental themes, the regular transactions in the SNA relating to the environment are isolated and explicitly shown. These transactions cover the production of waste treatment services (both purchased and self-produced), the production of consumer and intermediate goods designed to protect the environment, and environmental taxes.

More recently, the Netherlands has developed balance sheet accounts for monetary and physical measures of natural resource stocks. Ultimately these will be linked with the NAMEA system.

2.7 Sweden

Environmental accounting was initiated in Sweden in 1992 in response to a government directive. The call was for physical and monetary environmental accounts and indices that would provide insight into the links between the economy and the environment.

The accounting framework used for integrated environmental and economic accounting in Sweden is to a very large extent based on the NAMEA framework just described. Environmental themes addressed include degradation of natural resources and loss of environmental quality as a result of pollution, and the depletion of natural resources. The standard economic accounts are supplemented with physical data within the framework of the input-output accounts. These data focus on waste flows: greenhouse gas and other air emissions, emissions of nitrogen and phosphorous, and other waste flows from extraction and manufacturing industries categorised according to material, source and method of treatment. Greenhouse gas and volatile organic compound emissions are estimated from detailed energy-use statistics, which themselves form a component of the Swedish environmental and resource accounts.

Estimates of defensive expenditures for environmental protection are under development. These are expected to be isolated or shown as separate inputs within the economic accounts in the near future.

Complete balance sheet estimates in monetary and physical terms for land, forest and sub-soil assets are under development.

Future development will see the quality and detail of the existing accounts improved and accounts drawn up for a materials balance of toxic compounds. Wherever feasible, environmental indicators will be extracted and linked to the environmental themes.

2.8 France

In 1978, France embarked on a project to design an accounting system to assess, both quantitatively and qualitatively, the state and evolution of its “natural patrimony.” The nation’s natural patrimony, or natural wealth, incorporates the natural assets inherited from previous generations and is intended to embody the notion of ecological sustainability. Thus, the natural patrimony accounts were conceived to assess the interaction between the ecological, economic and social functions of natural assets.

Development of the patrimony accounts was motivated by the need to integrate the environment more effectively in economic policy. Early in their development, the benefits of linking the patrimony accounts to the national accounts were recognized and became a major impetus for the work. The objective was not the creation of an environmentally-modified economic aggregate that would serve as a welfare measure however. Rather, it was to provide a supplementary set of accounts suitable for analysing the trade-offs between the ecological, economic and social functions of the environment.

The natural patrimony accounts comprise three elements.

Component accounts describe the opening and closing stocks of natural assets in physical terms for a given period. The contribution from each of the factors, natural and human, that contributed to changes in stock levels during the period are also shown. Although the framework for the component accounts includes all assets, practical constraints have restricted their development to inland water, forest, soil, land use, and wildlife.

Ecozone accounts register the changes in land use and the status of ecosystems in qualitative and physical terms.

Agent accounts describe the interaction between the environment and human activity. The categories used in the classification of the interactions are those of the standard French SNA and deal with both economic and non-economic activities. The agent accounts measure a range of activities, from production and consumption through changes in resource stocks and environmental quality. They are a form of physical material and energy flow accounts. Recently, work has been initiated on waste emissions.

The three elements of the patrimony accounts, when taken together, allow the analysis of the environment according to economic, ecological and social functions.

In addition to the natural patrimony accounts described above, France has also developed *economic* patrimony accounts in selected areas within the framework of the SNA. As in most countries, the French national balance sheet assesses in *monetary* terms all fixed and financial assets held by economic agents (including housing, capital equipment and livestock). This list has been expanded in the economic patrimony accounts to include natural resources such as land, sub-soil resources and forests.

Environmental protection expenditures have also been compiled in France since 1986. These accounts are presently being updated and revised to correspond more closely with the methods outlined in the *Système européen de rassemblement de l’information économique sur l’environnement*[1] (SERIEE) (Eurostat, 1994a and 1994b).[2]

1. *European System for the Collection of Economic Information on the Environment.*
2. Chapter 5 outlines the SERIEE framework in more detail.

2.9 Summary

Despite variation in national priorities and individual preferences for particular accounting structures, there are identifiable trends in the workplans for environmental and resource accounting within the member countries of the *London Group*.

All member countries have developed, or are intending to develop, physical measures for the natural resource stocks that figure most prominently in their economic and political domains. With the exception of Italy, monetary measures of natural resource stocks will also be derived. The latter are intended for incorporation in national balance sheet accounts, as per the recommendations of the SNA93.

Material flow accounts in physical terms have also been elaborated by most *London Group* countries. These are typically formulated according to input-output accounting frameworks. The materials included in the accounts tend to match those for which data are compiled in resource stock accounts. Energy resources are almost universally represented in the material flow accounts. Based on the energy-use accounts, estimates of emissions of greenhouse gas and other fuel-related wastes are made in many countries.

Finally, all *London Group* countries have initiated measurement of environmental protection expenditures.

3 Natural Resource Stock Accounts

Introduction

The **Natural Resource Stock Accounts** (NRSA) are the first of the three major components of the System of Environmental and Resource Accounts described in this volume.

The NRSA currently comprise three accounts, one for each of the following:

- subsoil resources;
- timber; and
- land.

In general, the NRSA show annual estimates of the quantities and values of Canada's stocks of the above natural resources. The time period covered by the accounts varies depending upon the resource in question and whether the accounts are presented in physical or monetary units. Many of the physical accounts begin in 1961; time series of value estimates generally begin in the mid-1970s. The geographic scope of the NRSA is, in the main, national and provincial/territorial.

Table 3.1 outlines the natural resources that are currently included in the NRSA and provides details of the coverage of each. As can be seen, the accounts currently focus on natural resources that provide direct inputs into market activity. This initial orientation of the accounts has been chosen for two reasons. To begin with, physical stock data are most readily compiled, and monetary estimates most objectively made, for resources that are used directly in the economy. Second, these resources represent a component of our national wealth that has historically been excluded from Canada's national balance sheet. Inclusion of this natural wealth on the national balance sheet has been deemed a high priority, and the NRSA have been developed initially in large part to meet this need. More is said on the inclusion of natural resources on the national balance sheet throughout this chapter.

A broader view of the resources that might ultimately be covered in a set of natural resource stock accounts is presented in Table 3.2. This view includes resources that provide indirect-use and non-use benefits, as well as those that provide direct inputs into market activity (Section 3.2.2 discusses the various use values of natural resources in more detail). Future development of the NRSA will see their coverage expanded to include physical and monetary estimates of natural resources that are not directly used in the market, but which provide benefits to Canadians nonetheless.

Table 3.1
Natural Resource Stock Accounts

Resource		Geographic coverage	Time series	Valuation method
Subsoil assets	Crude oil	Alberta, Saskatchewan, British Columbia, Manitoba, Ontario and Canada	1961-1995	Net price Present value[1]
Subsoil assets	Natural gas and by-products	Alberta, Saskatchewan, British Columbia, Ontario and Canada	1961-1995	Net price Present value
Subsoil assets	Crude bitumen (surface mineable and in-situ)	Alberta, Canada	1967-1995	Net price Present value
Subsoil assets	Coal	British Columbia, Alberta, Saskatchewan, New Brunswick, Nova Scotia and Canada	1976-1995[2]	Net price Present value
Subsoil assets	Metals[3]	**Physical accounts**: provinces/territories and Canada **Monetary accounts**: mine type[4]	1976-1995	Net price Present value
Subsoil assets	Potash	Saskatchewan and New Brunswick and Canada	1976-1995	Net price Present value
Timber		Provinces/territories and Canada[5]	1961-1991[6]	Present value
Land		Ecozones, provinces/ territories and Canada	**land cover**: 1991 **land use**: 1971, 1981, 1991 and 1996 **land value**: 1961-1996	Observed market values

Notes:
1. As well as net price and present value valuations, replacement cost valuations for crude oil have been reported for Alberta (Born, 1992).
2. The monetary accounts for coal begin in 1975 rather than 1976.
3. Copper, nickel, zinc, lead, gold, silver, molybdenum, iron and uranium.
4. Monetary accounts for metals are compiled by mine type (gold; copper and copper-zinc; nickel-copper; silver-lead-zinc; molybdenum; uranium; and iron) because of the difficulty of valuing individual metals in polymetallic ore deposits.
5. The physical accounts exclude Prince Edward Island, Manitoba and Northwest Territories.
6. The monetary accounts for timber extend to 1995.

Each of the existing component accounts of the NRSA is described briefly below. Full descriptions of the concepts, sources and methods used in their development are presented in sections 3.3 through 3.5 of this chapter.

Subsoil Asset Accounts

The **Subsoil Asset Accounts** (SAA) record annual physical and monetary estimates for the stocks of Canada's "economically recoverable" reserves[1] of:

- crude oil;
- natural gas and its by-products (natural gas liquids and sulphur);
- crude bitumen (or tar sands);
- lignite, subbituminous and bituminous coal;

1. There are several more formal definitions of subsoil asset reserves used in the SAA. These are described in detail in Section 3.3.

Table 3.2
Scope of Physical and Monetary Accounts of Natural Resources

	Biological resources				
	Forests	Other biological resources	Land	Subsoil resources	Water
Physical accounts	Accessible, timber productive, non-reserved forests	Marine and freshwater fish, shellfish and terrestrial flora and fauna	Economically used (agricultural land, land under buildings and forestland)	Developed reserves (economically recoverable)	Stored water (reservoirs)
	Other forests		Other land (protected areas and recreational land for example)	Undeveloped reserves (economically recoverable) (partially completed) Undiscovered recoverable resources (partially completed)	Other surface water and groundwater (by quality rating)
Monetary accounts	Market value (excluding non-timber values)	Market and non-market values	Market value	Market value (developed reserves)	Market value
	Market and non-market values		Market and non-market values	“Option values” (undeveloped reserves)	Market and non-market values

Notes:
In general, the division of the monetary accounts parallels that of the physical accounts. For example, the physical account for forests is split into a portion for forestland used for timber harvest and another for other forestland. Similarly, the monetary account is split into a portion based on market values for forestland used for timber harvesting and market and non-market valuation of other forestland.
The shaded areas denote the physical and monetary accounts that have been completed to date in the NRSA.

- metals (copper, nickel, zinc, lead, gold, silver, molybdenum, iron and uranium); and
- potash.

Economically recoverable reserves are those that can be recovered under current technological and economic conditions.

The SAA take the form of reconciliation accounts. That is, they show estimates for opening and closing stocks of subsoil assets in each year, plus the volume changes that occurred during the year. Volume changes resulting from reserve discoveries, additions and depletion are recorded in both the physical and monetary accounts. The monetary reconciliation accounts include an additional balancing item: revaluation of reserve stocks due to changes in prices and costs. Section 3.3.3 presents further details of the reconciliation accounts of the SAA.

Beyond economically recoverable reserves, the SAA also show supplementary, point-in-time physical estimates for Canada’s total resource base. Currently, these estimates are limited to energy resources for the year 1992.[1] They supplement the estimates of economically recoverable reserves with estimates of reserves thought to be potentially recoverable in the future. This broader physical assessment is included in the SAA because the annual physical and monetary accounts measure only a (sometimes very small) fraction of total reserves. The estimates of the total resource base present a more complete picture of the resources available to Canada in the long run (Born, 1997).

Full details of the SAA are provided in Section 3.3 of this chapter.

Timber Asset Accounts

The **Timber Asset Accounts** (TAA) comprise physical and monetary accounts of Canada’s timber assets. Uses of Canada’s forests for purposes other than timber supply–as recreational areas or wildlife habitat for example–have not yet been considered in the TAA. Timber supply has been chosen as the initial orientation of the account since this is the principal economic use of the forest in Canada.[2]

In Canada, timber productivity and accessibility limit the portion of the forest that provides economic benefit and, therefore, the portion that can be considered an economic asset. For this reason, only Canada’s accessible, timber-productive, nonreserved forestland is represented in the TAA.

Like the Subsoil Asset Accounts, the **Physical Timber Asset Account** is presented as a reconciliation account. It provides annual opening and closing estimates of standing timber stocks and timber-productive land area, plus the changes in the volume of these stocks due to harvesting and natural events. The **Monetary Timber Asset Account**,

1. The total resource base estimates for energy are large and are revised only periodically. For this reason, the SAA does not show an annual time series of these estimates, but presents a periodic “snapshot” instead. The data required to show similar estimates for assets other than energy resources do not exist at this time.

2. Extension of the Timber Asset Accounts to include physical and monetary statistics for forestland uses other than timber production will be undertaken in the future. Estimates of stocks and values of parkland will be a primary focus of this development.

in contrast, presents only annual value estimates for standing timber stocks. It does not currently include value estimates corresponding to the annual volume changes shown in the physical account. Estimating the value of each component of the annual change in physical timber stocks is not possible given current data sources and valuation methods.

Both the physical and monetary timber accounts present time series beginning in 1961 at the national and provincial/territorial levels.[1]

Full details of the TAA are provided in Section 3.4 of this chapter.

Land Account

Like subsoil and timber assets, land is a key input into many economic activities. A number of unique attributes set land apart from these other resources however. First of all, land is not harvested or extracted, but is used “in place” instead. Second, the total stock of land in Canada is, for all intents and purposes, fixed. Finally, location is key in determining the use to which land is put. The Land Account has been structured to reflect these unique characteristics of land and it differs in a number of ways from the accounts just described for subsoil and timber assets.

- The Land Account is not represented as an *annual* time series of stock estimates. Significant changes to land resources do not usually occur over the span of a single year, but over several years or even decades. For this reason, the Land Account is updated on a multi-year cycle. Some components of the account are updated every two to three years (land cover for example); major revisions are made every five years following the release of new information from the censuses of population and agriculture.

- The Land Account is not represented as a series of provincial and national reconciliation accounts. Reconciliation accounts are suitable only for resources that are depletable; that is, for resources for which the total stock can be reduced (or augmented) from one period to the next. This is not the case for land. As noted above, the total stock of land in Canada is fixed and a reduction in the use of land for one purpose (agriculture for example) implies an increase in its use for another (urban land perhaps). Thus, changes in land stocks are best represented in a two-dimensional transition matrix showing the flows between stock categories. At this time, the data required to develop such a transition matrix for land are only partially available in Canada. The Land Account thus presents only beginning-of-period stock estimates by land category, without showing the flows that contribute to the changes in these stocks during each period.

- Finally, the importance of location in determining the characteristics and use of land demands that the Land Account be compiled using a detailed spatial framework. The spatial framework used in the Land Account is formed from the amalgamation of regions defined by ecological, political and statistical boundaries.

Incorporating the above characteristics, the Land Account forms a large, spatially-referenced database with five layers:

- a physical foundation;
- land cover;
- land use;
- land potential; and
- land value.

As with the other resource stock accounts, the time series of data presented in the Land Account varies significantly depending upon the land category in question. Thanks to Statistics Canada’s long-standing collection of agricultural statistics, estimates of agricultural land use are available back to 1901. Estimates of land used for other purposes begin in 1971. Detailed estimates of land cover for the entire country currently exist only for 1991.

Full details of the Land Account are provided in Section 3.5 of this chapter.

Other resources

The development of stock accounts for other natural resources has not progressed as far as that for subsoil, timber and land assets. This is mainly due to a lack of suitable data. In particular, despite the investment of considerable effort in assessing data sources, the development of a physical stock account of marine resources has not yet proven possible. Pelagic (or finned) fish and shellfish stocks are estimated by officials only when there appears to be a problem with a localized fishery, and then only for the species of concern. Thus, there exist no annual stock estimates by species for each fishery in the country and, therefore, no data from which an aggregate fish stock account could be compiled (Austin, 1996).

The situation is somewhat better for terrestrial animals that are of importance as game or for fur production. Population data of the sort that could be used to develop a stock account are often estimated for game species on the basis of reported hunting successes. Likewise, stocks of fur-bearing animals are estimated on the basis of the number of pelts harvested in a season. The use of these data to develop stock accounts for wildlife species is still being investigated.

3.1 Rationale, uses and linkages

Much of Canada’s economic wealth is attributable to the nation’s substantial stocks of natural resources. Yet for most

1. The Physical Timber Asset Account currently excludes Prince Edward Island, Manitoba and the Northwest Territories. A lack of suitable data for these regions precludes their inclusion in the account.

of our history, Canadians have taken these natural resources for granted, treating them as "free gifts of nature." This has changed. Canadians now recognize that their natural resource base is finite and that it must be managed for the benefit of both current and future generations. This recognition is translating more and more often into economic policy that looks beyond the conventional orientation of economic growth, setting instead targets for sustainable development.[1]

The traditional view of natural resources as "free gifts of nature" is reflected in the fact that the national accounts of all nations have historically assigned little or no value to resource stocks and environmental services. The Canadian National Balance Sheet Accounts (CNBSA), for example, have historically included the value of only a small portion of Canada's land[2] in the measurement of national wealth; all other resources have been excluded. As discussed in Chapter 1, this treatment will change as a result of the release of the latest version of the international guide to national accounting, the SNA93. The new version of this guide reflects a rethinking by its sponsoring organizations of the economic role of natural resources. The guide now provides useful directions for integrating environmental statistics into the national accounting framework. One of its major recommendations is that selected natural resources be recognized as economic assets and included in the estimate of national wealth presented in national balance sheet accounts.

Natural resources as assets

According to the SNA93, the conditions under which resources are rightly considered economic assets and included on balance sheet accounts are as follows:

> Naturally occurring assets over which ownership rights have been established and are effectively enforced...qualify as economic assets and [are to] be recorded in balance sheets. [Such assets] do not necessarily have to be owned by individual units, and may be owned collectively by groups of units or by governments on behalf of entire communities...In order to comply with the general definition of an economic asset, natural assets must not only be owned but be capable of bringing economic benefits to their owners, given the technology, scientific knowledge, economic infrastructure, available resources and set of relative prices prevailing on the dates to which the balance sheet relates or expected in the near future (Commission of European Communities *et al.*, 1993; p. 219).

1. For example, beginning in December 1997, each federal government department will be required to submit a Sustainable Development Strategy to the Office of the Commissioner of the Environment and Sustainable Development, a recently formed branch of the Office of the Auditor General. These strategies will require measures, or indicators, of sustainability.
2. Agricultural land and land under residential and commercial buildings.

The SNA93 recognizes four broad categories of natural resources (formally, "tangible non-produced assets") that generally meet the above criteria: land, subsoil resources, "non-cultivated biological resources" (timber and wildlife) and water.

Statistics Canada, along with statistical offices in many other nations, is complying with the SNA93's recommendations respecting natural resources and balance sheet accounts. Beginning in 1997, estimates of stock values for subsoil and timber assets will be added to the CNBSA. At a later date, the estimates of land value already included on the balance sheet will be improved and extended to include new categories of land (forestland and parkland for example). Biological resources (other than timber) and water will also be included on the balance sheet in the future, once suitable data sources and valuation methods are found.

The addition of natural resource assets to the national balance sheet recognizes the fact that these resources, although provided freely by nature, contribute significantly to Canada's income-generating potential. In other words, they are an important part of our national wealth.

Text Box 3.1 presents definitions of the natural resource assets that are currently measured in the NRSA. These definitions generally follow those of the SNA93 for tangible non-produced assets, with some minor differences.[3] Text Box 3.2 demonstrates how these assets (as well as those for which no data are yet available in the NRSA) are classified as non-produced assets in the CNBSA.

As can be seen in Text Box 3.2, national wealth is defined as the sum of all non-financial assets held by Canadian citizens, businesses and governments. Non-financial assets are divided into three groups: 1) produced assets that are the result of economic or human activity; 2) non-produced assets (or natural resource assets) that are required for economic activity but that have been produced by the environment; and 3) intangible assets (intellectual property for example). Until now, only the first of these categories (produced assets), plus the first three land categories, have been measured in the CNBSA. As of 1997, natural resource assets (timber and subsoil assets) will be added. No estimates of the value of intangible assets are currently included, or planned for inclusion, on the balance sheet.

Non-economic natural resources

Not all natural resources qualify as economic assets. In particular, natural resources over which ownership rights cannot be established cannot be considered economic assets in the SNA93 sense. These include resources such as air, major water bodies and ecosystems that are so vast or uncontrollable that effective ownership rights cannot be enforced. Likewise, resources whose existence has not been

3. The differences include the use of a social discount rate, rather than the suggested private rate, to derive asset values; expansion of the definition of mineral reserves to include both proven and probable, not just proven, reserves; and aggregation of cultivated and non-cultivated timberland into a single timber asset.

Text Box 3.1

Natural Resource Assets in the NRSA

Natural resource assets, in general, are those natural resources over which ownership rights can be enforced and from which economic benefits can be derived by the owners. They meet the criteria for qualification as economic assets as set out in the SNA93, where they are termed **tangible non-produced assets**.

Land assets include land associated with residential and non-residential buildings, agricultural land and land used for recreation or environmental protection (parkland for example).

Timber assets are those timber stocks that are capable of producing a merchantable stand within a reasonable period of time, that are physically accessible and that are not reserved for purposes other than harvesting.

Subsoil assets are restricted to *developed reserves* of subsoil resources; that is, those reserves that can be expected to be recovered through existing installations (wells or mines) under existing operating methods and economic conditions. **Undeveloped reserves** of subsoil resources are those that require further capital investment before extraction can occur; they are not considered economic assets because economic benefits cannot be derived from them in the immediate future. **Undiscovered recoverable resources** are those believed to exist on the basis of available geological and geophysical evidence, but which have not yet been shown to exist by drilling, testing or production.

Sources:
Commission of European Communities *et al.*, 1993; p. 309-310.
Born, 1997.

proven by exploration and development (undiscovered subsoil resources for example) or that are currently inaccessible (remote forests for example) are also not considered economic assets. Known resource reserves that do not yet provide economic benefit because the capital needed to exploit them is not in place are also not considered economic assets. (These resources may become economic assets at some future point as the result of advances in technology or changes in prices.)

The fact that a resource does not qualify as an economic asset does not preclude its inclusion in the NRSA however. Unlike the CNBSA, in which the focus is strictly on economic assets, the mandate of the NRSA is to present physical and, whenever possible, monetary estimates of all important natural resource stocks in Canada. Although the initial development of the NRSA has focused, with good reason, on resources that qualify as economic assets, future development of the accounts will expand this boundary to include

Text Box 3.2

Non-financial Assets of the CNBSA[1]

Non-financial assets (national wealth)

1 Produced assets
- 1.1 Capital (structures, machinery and equipment)
- 1.2 Consumer durables (autos, furniture and appliances)
- 1.3 Inventories
- 1.4 Other produced assets (monuments, valuables and collectibles)

2 Non-produced assets
- 2.1 Land
  - Residential land
  - Non-residential built-up land
  - Agricultural land
  - Land inventory[2]
  - Recreational and protected land
- 2.2 Timber
- 2.3 Wildlife
  - Fish
  - Other wildlife
- 2.4 Subsoil assets
  - Oil, crude bitumen and natural gas
  - Coal
  - Metals
  - Non-metals

3 Intangible assets
- 3.1 Goodwill[3]
- 3.2 Other intangible assets

Notes:
1. This is the classification of non-financial assets proposed for use in the CNBSA beginning in 1997.
2. Land inventory is the value of land held by developers for future development.
3. Goodwill is defined as the excess of the price paid for a business over the business' net worth.

natural resources that provide benefits outside of traditionally-measured economic activity.

3.1.1 Uses

A principal use of the NRSA is as the source of estimates of the values of Canada's natural resource asset stocks that are required to supplement the measure of national wealth in the CNBSA. As explained in Chapter 1, measurement of natural wealth is an important aspect of assessing the sustainability of economic development. Expanding the CNBSA to include the value of natural wealth alongside the traditional measures of produced wealth provides a more complete picture of Canada's total wealth. It allows assessment of the degree to which produced capital is used as a substitute for natural capital. Balance sheet data on natural

Text Box 3.3

Environment-economy Indicators from the NRSA

Land-use indicators

- share of prime agricultural land under cultivation
- urban-rural land use change

National wealth indicator

- annual value of natural and produced capital

Physical resource stock indicators

- annual stock estimates for timber, energy and mineral resources
- annual depletion of mineral reserves and harvest of timber stocks
- reserve life of energy and mineral resources
- total natural resource base

resources are also of interest for monitoring the availability and exploitation of these resources and for formulating environmental policies.

Environment-economy indicators

Beyond their contribution to the CNBSA, the NRSA also serve as the basis for environment-economy indicators in the areas of land-use, national wealth and physical measures of resource stocks. The indicators that are currently developed within these three areas are presented in Text Box 3.3. These indicators provide information about management of Canada's natural resource stocks and their use in the economy.

The land-use indicators show how land-use patterns have changed since the early 1900s. Such indicators provide broad measures of the pressure placed on our land resources by economic activity, addressing questions like:

- How quickly is rural land being converted to urban land?
- Of Canada's total urban land area, what share is occupying prime agricultural land?
- What percentage of total prime agricultural land is being cultivated over time?

The national wealth indicator measures the contribution of natural resources to Canada's national wealth and contrasts this with the wealth associated with produced assets. This indicator addresses questions like:

- Are we maintaining the value of Canada's natural wealth, thereby ensuring a steady flow of income from the exploitation of natural resources?
- To what extent are we substituting produced assets for natural assets? Are we maintaining total wealth (produced plus natural) over time, both in total and per capita?

Finally, the physical resource stock indicators provide physical measures of Canada's stocks of natural resources, offering insight into questions of the following sort:

- Do discoveries of energy and mineral resources keep pace with the depletion of these resources?
- Does natural growth offset harvest and other losses of our timber resources?
- What is the impact of resource depletion on the stock of natural resources and Canada's total resource base?

3.1.2 Linkages to other accounts

Relationship to other components of CSERA

Of the other components of CSERA described in this volume, the NRSA are most closely related to the Material and Energy Flow Accounts (MEFA; Chapter 4). The annual depletion or harvest of natural resource stocks recorded in physical units the NRSA represents a portion of the resource flows that are recorded in the MEFA.[1] For example, the timber harvest that is recorded in physical units in the TAA shows up in the MEFA as a physical flow of timber into the economy. Of the resources currently included in the NRSA, the MEFA present data for the flows of energy commodities only; further work is required to produce accounts for the flows of other resources.

The integration of data from the NRSA and the MEFA can be used to measure the impact of material and energy use on the stock of "virgin" resources in the environment. For example, quantities of recycled materials measured in the MEFA can be compared against the total demand for materials to assess the impact of recycling on the rate of depletion of resource stocks.

International comparisons

In 1994, the **United States Bureau of Economic Analysis** (BEA) produced the *Integrated Economic and Environmental Satellite Accounts*. These are strictly monetary accounts with no physical counterparts. Included in the asset account are values of timber, land and subsoil assets for the year 1987 (U.S. Bureau of Economic Analysis, 1994). Of all the international work done in the area of monetary valuation of subsoil assets, the methods used by BEA are the most sim-

1. The resource flows measured in the MEFA include those from resource imports and waste recycling, as well as those from extraction of virgin resources.

ilar to the methods employed in the NRSA. However, the valuation method for timberland differs from that used in the NRSA. The BEA's method is based on stumpage value estimates derived from observed data on market transactions in logging rights. The BEA's estimates of land value are based on observed real estate values for agricultural land and land underlying structures. This method is similar to that used by Statistics Canada to value agricultural and built-up land.

Australia has released experimental estimates of natural resource stock values as part of its national balance sheet and reconciliation accounts covering the years 1989 to 1992 (Australian Bureau of Statistics, 1995). Like Canada, a set of physical accounts for subsoil and timber assets are presented in addition to monetary accounts. The monetary accounts of subsoil assets present a range of value estimates based on a present value method using discount rates of 5, 7.5 and 10 percent. The Australian timber stock values are estimated by multiplying stumpage price per cubic metre by the volume of sawlogs and pulplogs harvested and discounting the result to a present value, again using a range of discount rates. Like the United States and Canada, Australia's land value estimates include only agricultural and commercial land, with no estimates for the value of other types of land.

The **World Bank** has produced estimates of wealth for 192 countries, including Canada, for the year 1994 (World Bank, 1997). The estimates include values for natural capital (minerals and fossil fuels, timber, non-timber benefits and various classes of land), human capital and produced capital. The values of land, timber and subsoil assets are estimated using a present value method with a discount rate of 4 percent. This is similar to the method used in the NRSA. Values for protected lands are based on the value of alternative uses of the land (that is, an opportunity cost approach).

Several European countries (notably Germany, France, the Netherlands and the United Kingdom), as well as the European Community, have made substantial progress in the area of land accounting.

The **European Community** initiated the *Coordination of Information on the Environment* (CORINE) program in 1985. It represents an environmental information system for the European Union that includes land-cover and land-use data. The CORINE project is expected to include 12 countries.

In **Germany**, land statistics are collected through CORINE and the *Statistical Information System on Land Use*. From these data, a land account will be set up for land use and land cover. Stock and flow accounts will show the effects of natural processes and human activities (Federal Statistical Office of Germany, 1994).

In **France**, CORINE is accompanied by an annual land-use survey, *Ter-Uti*, for France's land accounting program. Similar accounts to those produced by Germany will show changes in land use and land cover in a matrix format (Institute français de l'environnement, 1994).

Land accounting in the **Netherlands** includes changes in land cover, land use and land value. Land is classified using 35 use and cover categories. Like Canada, the value of land is included in the Dutch national balance sheet accounts.

Information on land cover, landscape features and habitats in the **United Kingdom** is obtained from the *Countryside Survey* and is to be integrated with the CORINE land-cover classification. The United Kingdom has also produced a classification of land-use changes, focusing on changes in urban and rural land uses (United Kingdom Department of the Environment, 1994).

3.2 Physical versus monetary accounts

A comprehensive description of the stocks of natural resources and their contribution to the economy is not possible without physical data. While monetary valuation of Canada's resources is necessary in order to calculate the wealth associated with natural resource assets, these values alone cannot clearly indicate trends in the remaining reserves of minerals or stocks of timber. Physical accounts of resource stocks provide measures of resource availability in the medium or long term by portraying the size of the nation's resource base and indicating whether or not we are maintaining that base (Born, 1997). A complete version of the NRSA is therefore produced in physical terms. This version serves as the basis on which the monetary version of the accounts is built.

While physical data play a necessary role in the measurement and evaluation of natural resource stocks, they are not themselves sufficient for a complete understanding of these stocks. Physical data are often difficult to aggregate due to the use of different units of measure (tonnes *versus* hectares for example). Even when physical stock measures are commensurable, the results of aggregation are often meaningless. Summing gold reserves with nickel reserves and reporting the result as “x” million tonnes of metallic minerals does not yield a result that can be readily interpreted. Thus, assessment of sustainability with physical data alone can be difficult.[1] If timber stocks increase in physical terms while natural gas stocks decrease, how can it be determined if the total stock of natural capital has increased, decreased or remained the same (Victor, 1991)? In many cases, the simplest way to make such comparisons is to calculate and compare the monetary value of the stocks.

3.2.1 Valuation in the NRSA

Valuation of natural resource asset stocks in the NRSA would ideally be based on observed market values for transactions in these assets. Such values are not available

1. See Section 1.3 in Chapter 1 for a fuller discussion of sustainable development and natural capital stocks.

for most resource assets however, since there are few transactions in resource assets in their “natural” state. Currently, market values are available in Canada only for agricultural land and land under residential and commercial buildings. Estimates of market value must be derived indirectly for other resources.

The concept of economic rent

The indirect estimation of market values of natural resource assets in the NRSA rests first on the estimation of a return to the resource, often referred to as **economic rent** (or resource rent).

The revenue generated from selling natural resources reflects both the costs of their extraction[1]–including the costs of materials, labour and produced capital–and a return to the resource itself. The latter is the economic rent attributable to the resource, which serves in the NRSA as the basis for estimating the market value of the total stock of the resource asset. Resource rent for a given resource asset is defined empirically as the difference between total revenue generated from extraction of the resource and all costs incurred during the extraction process, including the cost of produced capital, but excluding taxes, royalties and other costs that are not directly due to the extraction process.

Estimating resource rent

In Canada, governments are primarily the owners of the natural resources within their boundaries. As landlords, governments should in theory collect the entire rent derived from extraction of the resources they own. Resource rent is normally collected by governments through fees, taxes and royalties levied on companies that carry out extraction. The ideal means of estimating the economic rent attributable to a resource would be to equate it with the fees, taxes and royalties collected from the companies involved in the resource extraction. However, data on these charges are inappropriate in Canada,[2] so resource rent must instead be imputed using various indirect methods.

As noted above, resource rent is defined as the revenue generated from the sale of a resource asset less all costs incurred in its extraction, including the cost of produced capital. It is relatively straightforward to estimate the non-capital costs of resource extraction (that is, the costs of materials and labour). The data necessary to estimate non-capital costs are typically available directly from Statistics Canada surveys. Estimating the cost of the produced capital used in resource extraction, in contrast, is more difficult.

1. The term “extraction” when used to refer to natural resources in the general sense should be understood to include both the extraction of subsoil resources as well as the harvesting of renewable resources like timber or fish.
2. A number of difficulties can be cited. For example, not all rent is collected through fees, resource taxes and royalties. Some subsoil asset rent is collected through corporate income taxes for example, making it difficult to determine the exact amount of rent collected. In the case of timber assets, fees are set administratively rather than by public auction. It is therefore difficult to know whether or not they capture the full rent attributable to the assets.

In theory, the annual cost, C_K, of the produced capital[3] used in a resource extraction activity can be calculated as:

$$C_K = rK + \delta \qquad \text{Eq. 3.1}$$

where δ is the **annual rate of depreciation** of the produced capital stock and rK is the **return to produced capital**.

The **annual rate of depreciation** (δ), or capital consumption allowance, is an approximation of the value of produced capital that is lost (or “used up”) in each year that the capital is employed.[4] The depreciation estimate is based on the current replacement cost (rather than the original purchase cost) of the produced capital stock employed in the activity. The data required to make this estimate are readily available from Statistics Canada capital stock data.

Estimating the **return to produced capital** (rk) is less theoretically straightforward than estimating depreciation, as there are at least two ways in which the concept of return to produced capital can be interpreted. It can be interpreted, for instance, as the opportunity cost of the investment in the produced capital assets. This opportunity cost could be estimated as the average real rate of return on investment elsewhere in the economy. Alternatively, return to produced capital could be seen as covering the cost of financing the acquisition of the produced capital stock. In this case, use of the interest rate on bonds and/or the return on shares in resource industries is appropriate for use as the value of r in Eq. 3.1. Financing costs could be estimated using either the nominal interest rate (reflecting actual payments made) or the real rate (adjusted for inflation by deducting the expected rate of inflation from the nominal rate). Use of a real rate requires the assumption that produced capital stocks appreciate in value with time, offsetting part of the interest cost. This gain in value is realizable only if the capital goods are sold however.

The second interpretation of return to produced capital is the one adopted in the NRSA. An interest rate based on long-term industrial bond rates is taken as the value of r for use in estimating the return to produced capital in the accounts (written as r_i in what follows). A nominal value of this interest rate is used, on the assumption that capital goods used in resource extraction are fully depreciated and not sold in order to realize any gain in the assets' value.

Starting from Eq. 3.1 as the basis for estimating the cost of produced capital, two estimates of resource rent are made in the NRSA (Section A of Text Box 3.4). In the first of these estimates (Eq. 3.2 in Text Box 3.4), the cost of produced capital is taken to be equal to the annual depreciation of the produced capital stock employed in extraction (δ) plus the return to produced capital (r_iK). This estimate yields a lower

3. The produced capital stock used in a resource extraction activity is measured at the end of each year as the sum of the extraction industry's capital investments, net of accumulated depreciation.
4. The depreciation of the produced capital stock, which is a purely monetary measure, should not be confused with the physical depletion of the resource stock that occurs as a result of extraction.

Text Box 3.4

Alternative Methods of Valuing Subsoil and Timber Asset Stocks

A. Estimation of resource rent

$RR_{I} = TR - C - (r_{i}K + \delta)$ (lower bound) Eq. 3.2

$RR_{II} = TR - C - \delta$ (upper bound) Eq. 3.3

B. Valuation of subsoil assets

1. Net price I (positive return to produced capital)

$V_{I} = (RR_{I}/Q)S$ Eq. 3.4

2. Net price II (zero return to produced capital)

$V_{II} = (RR_{II}/Q)S$ Eq. 3.5

3. Present value (zero return to produced capital)

$$PV = \sum_{t=1}^{T} \frac{RR_{II}}{(1 + r_{g})^{t}}$$ Eq. 3.6

C. Valuation of timber assets

1. Present value I (positive return to produced capital)[1]

$PV_{I} = RR_{I}/r_{g}$ Eq. 3.7

2. Present value II (zero return to produced capital)

$PV_{II} = RR_{II}/r_{g}$ Eq. 3.8

Definition of symbols:

- δ = depreciation of the produced capital stock
- C = annual non-capital extraction costs, including fuel, electricity, materials, supplies and wages
- K = produced capital stock valued at replacement cost
- PV = present value of the resource stock
- Q = annual quantity of the resource extracted
- RR = annual resource rent
- S = stock of remaining recoverable or established reserves
- T = life of the reserve
- TR = total annual revenue from resource extraction
- V = net price value of the resource stock
- r_{g} = real provincial government bond rate
- r_{i} = nominal long-term industrial bond rate
- t = current year

Note:
1. The expression for calculating the present value of an income stream simplifies to (annual income)/(interest rate) when the time period is infinite.

bound on resource rent, as a portion of the total return to capital in the resource extraction activity is explicitly assigned to the produced capital; this portion is represented by $r_{i}K$.

In theory, Eq. 3.2 is the correct method of estimating resource rent. Rent should be net of all extraction costs, including full produced capital costs, to accurately represent the return to the subsoil asset. There is, however, uncertainty regarding the estimation of the return to the produced capital ($r_{i}K$), particularly when resource rent is small. In the case of coal and gold, for example, resource rent sometimes becomes negative after the deduction of the return to produced capital. The reasons for this are discussed in Born (1995). Negative resource rents suggest that the assumptions made regarding the return to produced capital in Eq. 3.2 may be inappropriate. By fixing the return to produced capital at $r_{i}K$, no allowance is made for relatively low rates of return to produced capital that are observable in the subsoil resource extraction industries.

The second estimate of resource rent made in the NRSA (Eq. 3.3 in Text Box 3.4) addresses the uncertainty associated with estimating the return to produced capital. As can be seen in Text Box 3.4, Eq. 3.3 includes only the depreciation of the produced capital stock in the cost of produced capital. Thus, the total return to capital in the extraction activity is assigned to the resource, the return to the produced capital stock being given a zero value. The resulting estimate yields an upper bound on resource rent.[1]

The “true” rent attributable to a given resource asset will lie somewhere between the lower and upper bounds established by Eq. 3.2 and Eq. 3.3.

Estimating resource stock values

As shown in sections B and C of Text Box 3.4, the two estimates of resource rent resulting from the contrasting assumptions regarding the cost of produced capital are applied in the estimation of subsoil and timber asset stock values in the NRSA (Eq. 3.4 to Eq. 3.8). The use of both rent estimates results in lower- and upper-bound estimates of the value of Canada’s resource asset stocks. Until a sound empirical means of estimating the return to produced capital can be found, both estimates of resource rent will continue to be used in stock valuation. As just mentioned for rent, the “true” stock values will lie somewhere between the lower and upper bounds established by the methods presented in Text Box 3.4.

1. For a more detailed discussion of the cost of produced capital see Born (1992 and 1995b).

Estimating the market value of any resource asset stock is complicated by the fact that extraction of the stock takes place over a long time period. In theory, the market value of a resource asset stock should equal the discounted value of the future stream of resource rent realizable from the stock. Discounting future rent to a present value is necessary because, from today's perspective, income earned from resource extraction in the future is worth less than that earned today.[1] This is the essence of the present value methods that are presented in Text Box 3.4 (Eq. 3.6, Eq. 3.7 and Eq. 3.8).

A second method of stock valuation–the net price method–is applied to subsoil assets in the NRSA (Eq. 3.4 and Eq. 3.5 in Text Box 3.4). As explained below, this method, which is based on the so-called Hotelling model,[2] eliminates the need for discounting future income by making certain assumptions about the rate of increase of resource prices. International consensus has not yet settled which method of subsoil asset valuation is the most appropriate, net price or present value. The NRSA therefore presents stock value estimates for Canada's subsoil assets based on both methods and will continue to do so until such time as consensus is reached on a single valuation method.

Valuation of non-renewable resources

As just noted, the valuation of non-renewable resource stocks (subsoil assets) is carried out using both the present value method and the net price method in the NRSA (Section B of Text Box 3.4).

The net price method is based on the Hotelling model, which assumes that under certain market conditions non-renewable resource rent will rise at a rate equal to the rate of discount (or interest rate) as the resource becomes scarce.[3] Under these circumstances, the value of the resource stock can be calculated simply as the current rent per unit of resource times the size of the stock (Landefeld and Hines, 1985). Because rent rises over time at a rate that is exactly sufficient to offset the discount rate, there is no need to discount future resource income.

Two net price calculations are employed for valuing subsoil assets in the NRSA, (Eq. 3.4 and Eq. 3.5 in Text Box 3.4), one for each of the two methods of estimating resource rent described above.

It is well documented in the literature that the net price method suffers from several empirical and theoretical weaknesses.[4] An alternative valuation of subsoil assets based on the present value method is therefore presented in the NRSA. The present value method is implemented first by assuming that the current annual rent from a subsoil asset extraction activity will remain constant for the life of the reserve. The stock value is then calculated as the discounted present value of a series of constant rent returns over the life of the asset (Eq. 3.6 in Text Box 3.4).

More complete explanations of the net price and present value methods as they are applied to the valuation of subsoil assets are presented in Section 3.3.2.

Valuation of renewable resources

If one assumes that harvesting can be sustained indefinitely, the value of a renewable resource asset stock can be calculated as the discounted present value of an indefinite annual stream of rent generated from harvesting the stock. This approach is used to value Canada's timber asset stocks in the NRSA. Two variations of this present value method are shown in Text Box 3.4 (Eq. 3.7 and Eq. 3.8), one for each of the two methods of estimating resource rent described above. This method of timber asset valuation is explained in more detail Section 3.4.2.

What discount rate to use?

As discussed above, resource assets for which returns are either delayed (growing timber) or spread over a lengthy period of time (mineral deposits) can be valued by discounting the expected future income to a present value. Doing so first requires the choice of a discount rate, a choice which is often the subject of considerable debate.

The discount rate (that is, the rate used to discount future income) expresses a time preference: the preference of an asset's owner for income today rather than in the future. This time preference will vary depending on the ownership of the asset. In general, individuals and businesses will have higher rates of time preference than governments. That is, individuals and businesses will tend to demand a quicker return from ownership of a resource asset than will governments. Higher rates of time preference translate into higher discount rates. A typical "private" discount rate appropriate for individuals or businesses might be in the range of seven or eight percent annually. A government, or "social," discount rate might be a few percentage points lower, reflecting the longer time perspective (that is, lower time preference) that governments are able to take.

In addition to time preference, discount rates can also reflect the risks associated with the future returns expected from resource assets. These risks include the possibility of price and cost changes or uncertainty about the amount or quality of the asset available for extraction. In the NRSA, these risks are accounted for otherwise in the stock valuation methods and the discount rate does not include a risk factor. Uncertainty about prices and costs is eliminated in the NRSA by the assumption that recent average prices and costs will remain constant into the future. Uncertainty about the extent or quality of resource stocks is dealt with by

1. Unless the price, or rent, of the resource asset rises at a rate matching the rate of income growth attainable in alternative investments; that is, unless the price increases at the rate of interest. Historically, this has not proven to be the case for most resource assets.
2. After the seminal work on natural resource valuation by Harold Hotelling (1931).
3. The Hotelling model is generally assumed not to apply to renewable resources, which, if sustainably managed, do not become scarce. Renewable resources that are not sustainably managed, but depleted instead, can in theory be valued using the Hotelling model.
4. Section 3.3.2 discusses some of these weaknesses.

choosing conservative stock estimates as the basis for valuation.[1]

Another type of risk, the risk that price inflation will erode the relative value of future returns, is also excluded from the discount rate used in the NRSA. Excluding inflation from the discount rate by using a real (or inflation adjusted) discount rate is consistent with the assumption that recent average prices and costs will remain constant into the future.

Since provincial governments are typically the owners of natural resource assets in Canada, the average provincial government real borrowing rate experienced over the period since 1961 is taken as the discount rate in the NRSA. This rate is assumed to represent pure time preference with a risk factor of zero, as this is the rate that investors earn on risk-free government bonds. The actual rate used, four percent *per annum*, is in line with estimates of the average real rate of return on long-term government bonds in Britain and the United States over the past two to three decades.[2]

Valuation for the CNBSA

As mentioned earlier, a principal function of the NRSA is to provide estimates of resource asset stock values for inclusion on the CNBSA. Although the NRSA themselves currently present a range of values for subsoil and timber assets, a single value is chosen for inclusion on the balance sheet so that only one estimate of national wealth is presented there.

The SNA93's recommended method of valuing natural resource assets for inclusion in balance sheet accounts is based on a present value calculation. Thus, the present value methods presented in Text Box 3.4 are used as the basis for estimating the values of timber and subsoil asset stocks that are entered in the CNBSA. In the case of timber assets, present value II (Eq. 3.8) is used as the basis for the balance sheet valuation. This calculation assumes no return to capital in the estimation of timber resource rent, yielding an upper bound on the value of Canada's timber assets. Only one present value calculation is done for subsoil assets (Eq. 3.6); like present value II for timber assets, the present value calculation for subsoil assets assumes no return to capital in estimating subsoil asset rent.

3.2.2 Other market and non-market values

Beyond their value as direct inputs into market activity, much of the value associated with natural resources (or, more generally, the environment) is not captured in the stock valuations in the NRSA. Although there is no generally accepted framework for classifying all the values associated with natural resources or the environment, the following list covers many of the values.

Use values

- **Direct-use values** include the value of extraction of natural resources. The value of recreation and other non-consumptive uses of nature, such as aesthetic appreciation, can also be included among direct-use values. Some direct-use values are part of measured market activity (the value of resource extraction and recreation for example). Others could be described as providing non-market benefits or having non-market value (the value of aesthetic appreciation for example).

- **Indirect-use values** are the values associated with the use of the functions provided by natural resources or the environment. These include carbon fixation, the provision of oxygen, and ultra-violet radiation absorption.

Non-use or existence values

- **Existence values** are the values placed on (or the benefits obtained from knowing about) the existence of natural resources. They are independent of the use of the resources. Existence values can be based, for example, on sympathy for a certain species. Donations to environmental funds that preserve remote environments that most donors are likely never to visit are offered as evidence that existence values are a real component of resource values.

- **Bequest values** are the values associated with assuring that natural resources are passed on to future generations.

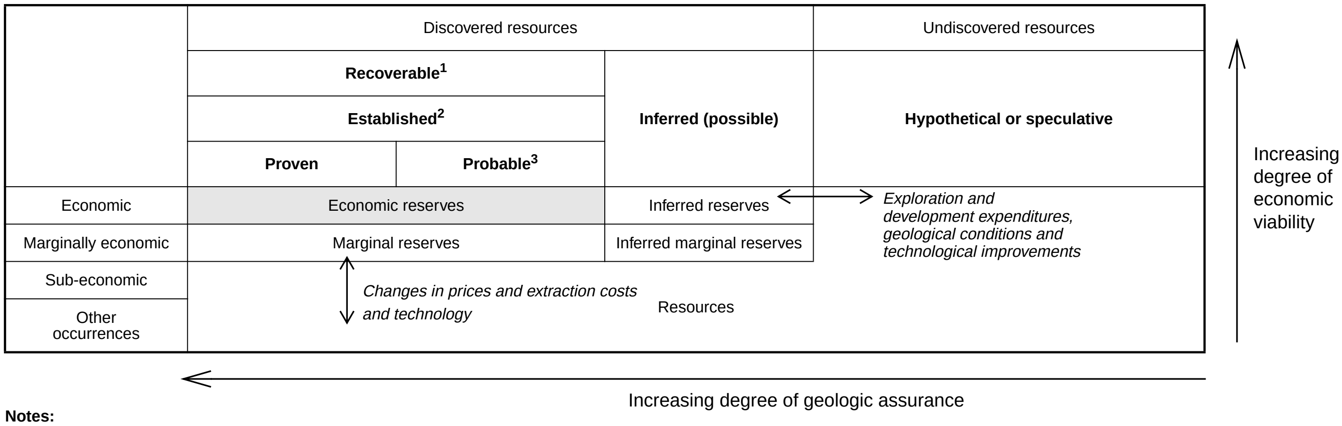
- **Option values** are the values associated with assuring the future availability of resources for one's own possible future use. An example is the value placed on maintaining natural resources as future sources of genetic material for drugs or hybrid agricultural crops.

Non-consumptive direct-use and non-use values can be measured by asking what people are willing to pay for the benefits. Existence value, for example, can be measured by asking how much people are willing to pay to protect or preserve a site. The value of recreational use could be measured by determining the maximum user fee that people are prepared to pay for a certain recreational experience. The total value of recreational use would include travel and other costs incurred by the user as well as the fee that the user is willing to pay.

Although considerable work will be required before any non-use or indirect use values can be incorporated in the NRSA, doing so is an important goal for the future. As a first step, physical accounts of parkland and protected areas are being developed, with monetary valuation using the techniques discussed above to follow.

1. The physical stock estimates on which the subsoil asset values are based can be considered conservative since only reserves with a high probability of existence are measured. Similarly, valuation of timber asset stocks is based on harvest volumes set by provincial forest managers; these volumes are determined by considering probable future growth and natural loss and, therefore, can be considered reasonable estimates of the sustainable harvest level.
2. For a more detailed discussion of discount rates and their theoretical underpinnings, see Beckerman (1993).

Figure 3.1
McKelvey Box



Notes:
1. Economic reserves of coal and uranium are termed “recoverable.”
2. Economic reserves of crude oil, natural gas and crude bitumen are termed “established.”
3. Economic reserves of metals and potash are termed “proven and probable.”

The principal physical and monetary accounts of the SAA represent “economic reserves” only (the shaded area in the figure). These are discovered and economically defined resources. Supplementary physical accounts of the SAA include both discovered and undiscovered reserves and resources.

Source:
Adapted from McKelvey, 1972.

3.3 Subsoil Asset Accounts

As mentioned in the introduction to this chapter, the Subsoil Asset Accounts record annual physical and monetary estimates for Canada’s stocks of:

- crude oil;
- natural gas and its by-products (natural gas liquids and sulphur);
- crude bitumen (or tar sands);
- lignite, subbituminous and bituminous coal;
- metals (copper, nickel, zinc, lead, gold, silver, molybdenum, iron and uranium); and
- potash.

The SAA’s stock estimates begin in 1961 for crude oil and natural gas and in 1976 for other subsoil assets. The physical stock estimates and one set of monetary stock estimates[1] are presented in reconciliation accounts showing opening and closing stocks of remaining reserves from year to year, plus annual reserve additions and depletion.

Much of the focus of the literature on subsoil asset accounting is on the correct means of valuing the depletion of mineral reserves and incorporating this value into domestic income figures (that is, GDP and NDP) (Ward, 1982; Hartwick, 1988, 1989, 1990a, 1990b and 1991; Repetto *et al.*, 1989; El Serafy, 1989; and Devarajan and Weiner, 1990). While issues of depletion are discussed briefly in this chapter, the scope of the SAA is broader than the measurement of depletion. The SAA include estimates of quantities and values of subsoil asset stocks as well as the annual flows (both additions and depletions) that are associated with these stocks.

1. As is explained in more detail below, several monetary valuations of subsoil asset stocks are presented in the SAA. Only one of these (present value) is included in the reconciliation account.

3.3.1 Physical Accounts

The Physical Subsoil Asset Accounts (PSAA) present annual estimates of the quantities of subsoil asset stocks (or reserves)[2] occurring in Canada. One of the major challenges in compiling these accounts is determining what portion of the total **resources** found in Canada are rightly considered **economic reserves** and therefore measured in the PSAA.

Subsoil **resources** are defined as all deposits of subsoil assets occurring in Canada, whether these deposits are known to exist as a result of exploration or whether they are hypothetical or speculative. By definition, total resources can never be measured accurately, as a portion of the total must always remain uncertain. **Economic reserves** of subsoil assets, in contrast, are defined as resources that are known to exist with a high degree of geological certainty and that are economically viable under current market and technological conditions. They are those resources that meet the SNA93 criteria for treatment as tangible non-produced assets (see page 24).

As alluded to above, reserves and resources are generally classified by the degree of economic viability and geological certainty with which the assets are known to exist. The McKelvey Box shown in (McKelvey, 1972) illustrates a classification of subsoil reserves and resources with respect to economic viability (vertical axis) and geological certainty

2. The terms “reserves” and “stocks” are used interchangeably with respect to subsoil assets.

Table 3.3
Subsoil Asset Reserve Classification

Subsoil asset	Reserve definition
Crude oil	Established
Natural gas (marketable)	Established
Natural gas by-products[1]	Established
Crude bitumen (tar sands)	Established
Coal[2]	Recoverable
Uranium	Recoverable
Other metals[3]	Proven and probable
Potash	Proven and probable

Notes:
1. Ethane, propane, butane, pentanes-plus and sulphur.
2. Bituminous, subbituminous and lignite.
3. Iron, nickel, copper, zinc, lead, molybdenum, gold and silver.

(horizontal axis). The boundary between discovered and undiscovered resources fluctuates as the result of mining companies' investments in exploration and development, and differing geological conditions.

The boundary between economic reserves and sub-economic resources is affected by the relationship between prices and extraction costs, and technological improvements. Discovered reserves are those that occur in producing areas, and undiscovered resources are those in non-producing areas or in non-productive strata in producing areas.

The literature dealing with subsoil resources has not yet evolved a single naming convention for reserves. Thus, economic reserves of crude oil, natural gas and its by-products, and crude bitumen are termed *established*; those for coal and uranium are termed *recoverable*; and those for metals and potash are termed *proven and probable* (Table 3.3). These are the reserve definitions adopted for use in the physical accounts of the SAA. The reason for the adoption of these definitions is twofold: the data obtained from provincial and federal government departments are reported in this manner; and the definitions represent conceptually similar measures for each of subsoil resource. A detailed description of the rationale for the reserve and resource definitions used in Canada is beyond the scope of this volume.

Definition of crude oil, crude bitumen and natural gas reserves

Reserve estimates for crude oil, crude bitumen (tar sands), natural gas and its by-products (propane, butane, ethane, pentanes plus and sulphur) are provided by the Canadian Association of Petroleum Producers,[1] the Alberta Energy and Utilities Board (formerly known as the Alberta Energy Resources Conservation Board),[2] the National Energy Board (1988) and other provincial government agencies. They are reported by these agencies as *established* reserves. Established reserves are:

> those reserves recoverable under current technological and present and anticipated economic conditions, specifically proved by drilling, testing or production, plus that judgement portion of contiguous recoverable reserves that are interpreted to exist from geological, geophysical or similar information, with reasonable certainty (Tanner, 1986; p. 22).

The PSAA measure quantities of remaining established reserves, annual extraction of these reserves, and additions as the result of discoveries, development, revisions and enhanced oil recovery.[3]

The definition of established reserves allows for advances in current technology and a reasonable forecast of economic conditions. Tanner (1986) suggests that the definition of proven reserves is too conservative for macro-economic planning and that established reserves better reflect the resources that will be available for national production and consumption.

Definition of coal reserves

Coal resources and reserves are defined according to three sets of criteria: resource feasibility, assurance of existence and technology (Table 3.4). A detailed description of this classification is presented by Born *et al.* (1995). Although the uncertainty of coal reserve and resource estimates in these categories varies, experience with Canadian coal deposits suggests that measured resource quantities are normally known within 10 percent, indicated resources within 20 percent and inferred resources within 50 percent of estimates.

Coal that is anticipated to be mineable based on feasibility studies, existing technology and current economic conditions is classified as a recoverable resource in the *technology class*. In-place coal is equivalent to recoverable resources before recovery factors are applied (Hughes *et al.*, 1989).[4]

Portions of measured and indicated coal resources of immediate interest that are the most likely to be developed commercially are called **reserves**.[5] Only those reserves that are recoverable in active mines are included in the PSAA, since only they have a high probability of being extracted in the foreseeable future.

1. Canadian Association of Petroleum Producers, *Statistical Yearbook*, Calgary.
Canadian Association of Petroleum Producers, *CPA Review*, Calgary.
2. Alberta Energy and Utilities Board, *Alberta's Reserves of Crude Oil, Oil Sands, Gas, Natural Gas Liquids and Sulphur*, ERCB ST.
3. Primary recovery methods generally obtain about 30 percent of the crude oil in the ground (60 to 90 percent for natural gas in Alberta). Enhanced ("secondary and tertiary") recovery methods are employed to increase these recovery rates.
4. Recovery factors are percentages that reflect the portion of in-place reserves likely to be extractable from a given seam. Recovery factors range from 50 to 90 percent depending on the type of coal seam in question.
5. In Alberta, coal reserves are called *in-mine established* reserves, and are approximately equivalent to recoverable reserves in active mines.

Table 3.4
Coal Resource and Reserve Classification

	Coal resources		Coal reserves	
Feasibility class	Immediate interest	Future interest	Active mines	Not in active mines
Assurance class	Measured, indicated inferred, speculative		Measured and indicated (established)	
Technology class	In-place		Recoverable	

Source:
Hughes, *et al.*, 1989.

Table 3.5
Coal in Canada

Coal type	Potential uses	Location	Share of 1992 Canadian production
Anthracite	Thermal coal, source of carbon for chemical production.	Nova Scotia	-
Bituminous	Metallurgical and thermal coal	British Columbia	26
		Alberta	16
		Nova Scotia	7
		New Brunswick	1
Subbituminous	Thermal coal	Alberta	35
Lignite	Minesite thermal coal	Saskatchewan	15

Source:
Born *et al.*, 1995.

So that Canada's coal reserves are accurately depicted, the coal account of the PSAA is presented by type of coal. Canadian coal ranges from lower quality lignite and subbituminous coal to higher quality bituminous and anthracite coal. Table 3.5 shows the different types of coal found in Canada and their uses, location and production share in 1992. Note that subbituminous coal and lignite are reported together in the PSAA.

Definitions of metal and potash reserves

The physical accounts of metals include reserve estimates for copper, nickel, zinc, lead, gold, silver, molybdenum, iron and uranium. Estimates of potash reserves are also included in this component of the PSAA. Reserve data for iron and potash are not readily available in Canada and are obtained instead from the U.S. Bureau of Mines.[1]

The physical accounts measure **proven** and **probable** reserves of metals and potash in producing mines and deposits. **Proven** reserves are defined as:

> the estimated quantity and grade of a mineral body for which information is so well established with respect to size, distribution of values, grade, deposit walls, and thickness, that there is the highest degree of confidence as to the quantity and grade that can be mined at a profit (Canadian Institute of Mining, Metallurgy and Petroleum, 1994).

A **probable** reserve is defined as:

> the estimated quantity and grade of a mineralized body for which sufficient information on continuity, extent, grade distribution, operating and capital costs, etc., is available to form the basis of a study indicating an economically viable operation at long-term forecast average metal prices. This could require at least a preliminary feasibility study for a future mining operation with a confidence level high enough to allow positive decisions concerning major capital expenditures (*op. cit.*).

Companies are able to estimate proven reserves with an accuracy of five percent, while probable are estimated within ten percent (Table 3.6).

Metals contained in mineral resources classified by companies as "possible" are not included in reserve totals, nor are metals contained in deposits that have not advanced beyond the exploration or deposit appraisal stages. Whenever possible, only recoverable metal in mineable ore is included in reserve totals so as to exclude losses inherent in the mining process (Lemieux, 1995).[2]

Definition of uranium reserves

For purposes of the SAA, reserve data obtained from the Uranium Resource Appraisal Group of Natural Resources Canada (Whillans, 1997) are aggregated to reflect the reserve classifications used for other subsoil resources. These reserves, which are those that are mineable at the prevailing uranium prices at the time of the reserve assessment, are termed **recoverable.**[3]

Canada's subsoil resource base: supplementary physical SAA

Beyond the detailed, annual physical accounts of economically recoverable reserves, the PSAA also included supplementary, point-in-time accounts of Canada's **ultimately recoverable resource base**. Ultimately recoverable resources are defined as the total of **discovered** and **undiscovered** recoverable resources. Discovered recoverable resources are those resources that are estimated to be recoverable from known deposits using current technology and under current economic conditions.[4] Undiscovered recoverable resources are those that are estimated to be recoverable from resources that are believed to exist on the basis of available geological and geophysical evidence but have not yet been shown to exist by drilling, testing or production.

1. U.S. Bureau of Mines, *Mineral Commodity Summaries*, Washington DC.
2. Recoverable metal is defined as total metal in the ore less losses due to the milling, smelting and refining processes. Not all metal reserve data are reported net of these losses.
3. For an extensive description of the uranium reserve classification used in Canada, see Energy, Mines and Resources (1991).
4. Discovered recoverable resources are equivalent to economic reserves.

Table 3.6

Metal Reserve and Resource Classification by Exploration and Development Phase

	Mineral resource assessment	Mineral exploration	Mineral deposit appraisal	Mine development	Mineral production
Accuracy of estimates[1]	+/- 100%	+/- 100%	+/- 60% +/- 40% +/- 20% +/-10%	+/- 10%	+/- 5%
Investment	Moderate	Low, but increasing, investment Very high, but decreasing, risk of failure and financial loss	Much larger and increasing investment High, but decreasing, risk of failure	Large industrial investment	
Mineral Inventory	Undelimited mineral resources		Delimited mineral resources	Ore reserves	
	Speculative	Hypothetical Inferred	Indicated and measured	Proven and probable	

Notes:
1. Expected margin of error of estimates at the 90% confidence level.
The Shaded area denotes the reserves that are included in the physical and monetary accounts of the SAA.
Source:
Lemieux, 1995.

The broader physical assessment of ultimately recoverable resources is included in the SAA because the main physical and monetary accounts, being limited to economic reserves, measure a (sometimes very) small fraction of total resources. Economic reserves are conservative estimates of available stocks based on current technology and markets. In the case of crude oil, remaining economic reserves represent 38 percent of known reserves and only 11 percent of ultimately recoverable resources. For crude bitumen, economic reserves represent only one percent of known reserves. For natural gas, economic reserves are 62 percent of known reserves and 13 percent of ultimately recoverable resources. The estimates of the ultimately recoverable resource base present a more complete picture of the resources available to Canada in the long run (Born, 1997).

Currently, the supplementary physical accounts of ultimately recoverable resources are limited to energy resources (oil, natural gas, crude bitumen, coal and uranium) for the year 1992.[1] The estimated ultimately recoverable energy resources are large and the estimates are revised only periodically. For this reason, the SAA does not show an annual time series of ultimately recoverable resource estimates, but presents periodic "snapshots" instead.

3.3.2 Monetary accounts

The Monetary Subsoil Asset Accounts (MSAA) present annual estimates of the value of Canada's economically recoverable reserves of subsoil assets. A principal purpose of the MSAA is to value subsoil asset stocks for inclusion in the CNBSA.

As explained in Section 3.2.1, valuation of subsoil assets is ideally based on observed market values for transactions in these assets. Such values are not generally available however, as there are relatively few transactions in subsoil assets in their underground state. Indirect methods of valuation are therefore used to estimate the market value of subsoil asset stocks in the MSAA.

For the purpose of the MSAA, only those reserves that are recoverable using existing machinery, equipment and structures, and under current economic conditions are measured. These are the reserves defined above as "established" in the cases of oil, natural gas and crude bitumen, as "recoverable" in the cases of coal and uranium, and as "proven and probable" for metals and potash.

Calculation of subsoil asset stock values

Two methods of valuation are used to estimate stock values in the MSAA:

- net price
- present value.[2]

Many of the issues surrounding the use of these methods to value resource assets have already been discussed in Section 3.2.1 and are not given detailed coverage again in this section. Only the specific application of the methods to the valuation of subsoil assets is discussed at length here. For the reader's convenience, Text Box 3.5 repeats the algebraic descriptions of the net price and present value methods for subsoil assets presented earlier in Text Box 3.4.

Net price method

The net price method for subsoil asset valuation is based on the so-called Hotelling model (Hotelling, 1931). This model assumes that in a perfectly competitive market the price of the marginal unit of a non-renewable resource–net of extraction, development and exploration costs (including cap-

1. The data required to show similar estimates for assets other than energy resources do not exist at this time.

2. A third method of valuation, the replacement cost method, has also been applied to the valuation of oil and gas reserves in Alberta (Born, 1992). In this method, exploration and development costs per unit of reserve addition are multiplied by the volume of remaining established reserves to obtain the value of the stock. This method is considered experimental and is not discussed further in this volume. For those interested, more details on the method are provided by Born (1992).

Text Box 3.5

Methods of Valuing Subsoil Asset Stocks

Estimation of resource rent

$RR_I = TR - C - (r_i K + \delta)$ (lower bound) Eq. 3.2

$RR_{II} = TR - C - \delta$ (upper bound) Eq. 3.3

1. Net price I (positive return to produced capital)

$V_I = (RR_I/Q)S$ Eq. 3.4

2. Net price II (zero return to produced capital)[1]

$V_{II} = (RR_{II}/Q)S$ Eq. 3.5

3. Present value (zero return to produced capital)

$$PV = \sum_{t=1}^{T} \frac{RR_{II}}{(1 + r_g)^t} \qquad \text{Eq. 3.6}$$

Definition of symbols:

δ = depreciation of the produced capital stock

C = annual non-capital extraction costs, including fuel, electricity, materials, supplies and wages

K = produced capital stock valued at replacement cost

PV = present value of the resource stock

Q = annual quantity of the resource extracted

RR = annual resource rent

S = stock of remaining recoverable or established reserves

T = life of the reserve

TR = total annual revenue from resource extraction

V = net price value of the resource stock

r_g = real provincial government bond rate

r_i = nominal long-term industrial bond rate

t = current year

Note:

1. In the SAA, net price II is actually calculated as *[(TR - C)/Q]S - K*. See the discussion of net price II in the text for a proof of the equivalence between this formulation and Eq. 3.5.

ital costs)–will rise over time at a rate equal to the rate of interest. This is known as the Hotelling "r-percent" rule (Landefeld and Hines, 1985). Under such a regime there is no need to discount future income to account for the devaluing effect of inflation. This leads to the useful result that the value of the stock of a non-renewable resource can be calculated simply as the net price (or rent) per unit of resource times the size of the resource stock.[1]

Variations of this method have been used to value mineral assets in several recent studies. Repetto *et al*. (1989) used the net price method to calculate the value of petroleum reserves in Indonesia. Smith (1992) has calculated value estimates for crude oil and natural gas reserves in Alberta using a net price method similar to that used by Repetto *et al.*

Two variations of the net price method are used in the MSAA, one for each of the methods of estimating resource rent discussed in Section 3.2.1 (Eq. 3.2 and Eq. 3.3 in Text Box 3.5).

Net price I

The first version of the net price method (Eq. 3.4 in Text Box 3.5) employs the lower-bound estimate for resource rent calculated according to Eq. 3.2. In this estimate, the cost of the produced capital used in subsoil asset extraction is taken to include both the annual depreciation of the produced capital stock (δ) *plus* a return to the capital ($r_i K$). The latter is calculated as the produced capital stock employed in a given subsoil asset extraction activity (*K*) multiplied by the average long-term corporate bond rate in Canada (r_i).

In net price I, per-unit subsoil asset rent is first calculated by dividing the rent from Eq. 3.2 (RR_I) by the annual quantity of subsoil asset extracted (*Q*). The rent per unit of asset is then multiplied by the quantity of remaining reserves (*S*) (taken from the PSAA) in order to estimate the market value of the asset stock. As net price I makes use of the lower-bound estimate of resource rent, the resulting estimate of the market value of the stock also represents a lower bound.

Net price II

Net price version II (Eq. 3.5 in Text Box 3.5) makes use of the upper-bound estimate of resource rent calculated according to Eq. 3.3. This results in upper-bound estimates of the market value of subsoil asset stocks. With the exception of the use of a different estimate of resource rent, net price II is theoretically identical to net price I. It should be noted, however, that the actual form of net price II that is used in the MSAA differs from that presented in Eq. 3.5. The derivation of the form of net price II used in the MSAA is given below.

First, re-writing Eq. 3.5 with RR_{II} expanded into its components gives:

$V_{II} = (RR_{II}/Q)S$ Eq. 3.5

$= [(TR - C - \delta)/Q]S$ Eq. 3.5a

$= [(TR - C)/Q]S - (\delta/Q)S$ Eq. 3.5b

1. The net price method is actually a special case of the present value method in which average long-run market equilibrium occurs (that is, the net price rises at the rate of interest) and the rise of the net price exactly offsets the discount rate.

Given an assumption of a constant annual rate of extraction (Q), S/Q can be taken to define the life of the reserve, T, and Eq. 3.5b can be rewritten as:

$$= [(TR - C)/Q]S - \delta T \qquad \text{Eq. 3.5c}$$

Assuming also that the produced capital employed in subsoil asset extraction has a useful life that is just equal to the life of the asset reserves, δT can be taken to be equal to K, the value of the produced capital stock (that is, the annual depreciation times the life of the capital stock is equivalent to the total value of the capital stock). Eq. 3.5c can thus be rewritten as:

$$= [(TR - C)/Q]S - K \qquad \text{Eq. 3.5d}$$

It is Eq. 3.5d that is the form of net price II used to calculate subsoil asset stock values in the MSAA. This form is favoured over Eq. 3.5 because it produces a smoother time series of stock value estimates than does the latter.

Weaknesses of the net price method

The ability of the net price method, and the Hotelling model on which it is based, to describe and predict the behaviour of actual subsoil asset markets is an area of considerable debate. Empirical analysis shows that the net price method tends to overestimate the market value of subsoil assets, a result that does not, in general, support the Hotelling model's assumptions. Indeed, the strong assumptions of the Hotelling model do not hold for subsoil asset markets in Canada, as the model ignores the constraints imposed by natural and economic factors in subsoil asset extraction. Furthermore, the price paths of crude oil and natural gas in recent years are quite different from those that would be predicted based on the Hotelling model.

Readers interested in a more detailed discussion of the Hotelling model and net price method are referred to Born (1992).

Present value method

Given that the net price method suffers from a number of shortcomings, an alternative method of valuation, based on the well-known formula for calculating the present value of a stream of future income, is also used in the MSAA (Eq. 3.6 in Text Box 3.5).

In order to apply the present value method to the valuation of subsoil asset stocks, certain assumptions about the future behaviour of key variables are first required. First, current annual rates of asset extraction are assumed to remain constant for the remaining life of the reserves. Second, current year-end resource prices and extraction costs (in real terms) are assumed to remain constant over the remaining life of the reserves. Although these assumptions may appear somewhat restrictive, in the absence of any impartial means of predicting the future behaviour of these variables constancy is the most objective assumption possible.

The issues surrounding the choice of the discount rate in the present value method have been discussed in detail in Section 3.2.1 and will not be repeated here. In all the monetary accounts of the NRSA, including the MSAA, a four percent annual discount rate is used. This rate is the approximate average real rate on provincial bonds since 1961.

As with net price II, the actual form of the present value calculation used in the MSAA differs slightly from that presented in Eq. 3.6. The calculation begins from Eq. 3.5d and arrives at an estimate of the present value of the stock by applying a discount factor:

$$PV = \phi\{[(TR - C)/Q]S - K\} \qquad \text{Eq. 3.6a}$$

where the discount factor, ϕ, is equal to:

$$\sum_{t=1}^{T} \frac{1/T}{(1 + r_g)^t}$$

Recalling that S/Q is assumed equal to T and that K is assumed equal to δT, and substituting into Eq. 3.6a for S/Q and K, it is possible to show that Eq. 3.6a is algebraically equivalent to Eq. 3.6:

$$PV = \sum_{t=1}^{T} \frac{\frac{1}{T}[(TR - C)T - \delta T]}{(1 + r_g)^t} \qquad \text{Eq. 3.6b}$$

which yields Eq. 3.6 upon multiplication through by T (recall that $RR_{II} = TR - C - \delta$):

$$PV = \sum_{t=1}^{T} \frac{TR - C - \delta}{(1 + r_g)^t} \qquad \text{Eq. 3.6}$$

Eq. 3.6a is the preferred form of the present value calculation in the MSAA because it yields a smoother time series of present values than does Eq. 3.6. A four-year moving average of the stock values from Eq. 3.5d is used when applying Eq. 3.6a in order to reduce the impact of the price volatility characteristic of mineral and petroleum markets on the present value of subsoil asset stocks.

Present value methods similar to that used in the MSAA have been used by other agencies and researchers for determining the value of subsoil assets. The U.S. Securities and Exchange Commission and Canadian Securities Commission both require that companies report the present value of future net cash flows from their projected production of proven reserves of oil and natural gas. The SNA93 also suggests using a present value method as the basis for resource asset valuation. The method is outlined by Landefeld and Hines (1985), Soloday (1980) and the U.S. Bureau of Economic Analysis (1994) for the valuation of oil, natural gas and metal reserves in the United States. Japan and Hungary have reported present values of their subsoil assets (Blades, 1980). Finally, Uhler and Eglington (1986) provide present value-based crude oil and natural gas reserve values for Alberta.

Valuation for the National Balance Sheet Account

As mentioned earlier, a principal function of the MSAA is to provide estimates of subsoil asset stock values for inclusion on the CNBSA. Although the MSAA currently present a range of values for subsoil assets, only those based on the present value method are included on the balance sheet. The choice of the present value method as the basis for the balance sheet valuation of subsoil assets is in line with the SNA93's recommendation on this subject.

The present value method yields negative values for certain subsoil asset stocks in some years. Since negative asset values present problems on balance sheets, a value of zero is substituted for negative subsoil asset stock values whenever they occur. This approach is adopted by most countries compiling resource stock estimates for balance sheet accounts.

3.3.3 Reconciliation accounts

Reconciliation accounts of both the physical and monetary estimates of subsoil asset stocks are presented in the SAA. The reconciliation accounts present opening and closing estimates of subsoil asset stocks in each year, plus the volume changes that occur during the year. The accounts are structured such that the closing stock in one year is equal to the opening stock in the following year. Volume changes resulting from discoveries, reserve development, changes in extraction technology, revisions in reserve estimates, and extraction are recorded in both the physical and monetary accounts. The monetary accounts also include estimates of changes in stock values resulting from revaluations caused by changes in resource prices. Table 3.7 shows the structure of the SAA reconciliation accounts

In the physical reconciliation account, the closing stock of a period is equal to the opening stock plus additions less depletion. Depletion is equal to the quantity of resource extracted during the period plus any downward revisions in reserve estimates. Additions are increases in the stock during the period as the result of discoveries, development, upward revisions to reserve estimates and enhanced oil recovery.

The monetary reconciliation accounts present the value estimates that result from the present value method. The basic accounting identity is:

value of the closing stock = value of the opening stock + additions - depletion + revaluations.

In order to value reserve additions and depletion, a per-unit asset value is first calculated by dividing the present value of the stock by the physical stock size. The value of additions is then calculated as the per-unit asset value times the reserve additions during the period. Similarly, the value of depletion is the calculated as the per-unit asset value times the quantity of asset extracted during the year. Revaluations due to price changes during the period are calculated residually:

revaluations = value of the closing stock - value of the opening stock - additions + depletion.

Table 3.7
Subsoil Asset Reconciliation Accounts

Physical account	Monetary Account
[1] Opening stock	**[1] Value of the opening stock**
[2] Additions	[2] Additions
[3] Depletion	[3] Depletion
	[4] Revaluation
[4] Closing stock [1 + 2 - 3]	**[5] Value of the closing stock [1 + 2 - 3 + 4]**

3.3.4 Data sources and methods

Crude oil, natural gas and crude bitumen

Reserves - The data sources used for crude oil, natural gas and crude bitumen employ an "established reserves" basis for the reserve data they report. This convention is also used in the SAA. The reserve data for crude bitumen are obtained from the Alberta Energy Resource Conservation Board.[1] Detailed descriptions of the data sources used for crude oil and natural gas are provided by Born (1992) and McCulloch (1994).

Measurement of oil and gas reserves is an imprecise science at the best of times, with frequent revisions in estimated recoverability during a well's life. The exact size of the economic resource is known only when the well has ceased to produce. In addition, there can be difficulties in separately identifying the various resources that are present in a given well. This is especially problematic for natural gas and its by-products. At the end of 1989, some 17 per cent of the remaining reserves of marketable[2] natural gas occurred as "associated" or as "solution natural gas." Non-associated gas is that found in natural reservoirs not in contact with crude oil, while associated gas is in contact with crude oil and solution gas is dissolved in crude oil at reservoir conditions.

Value and quantity of production - Data for the value and quantity of production of crude oil, natural gas and crude bitumen are available from Statistics Canada for the period 1973 to 1995.[3] For the period 1955 to 1972, the Canadian

1. Alberta Energy and Utilities Board, *Alberta's Reserves of Crude Oil, Oil Sands, Gas, Natural Gas Liquids and Sulphur*, ERCB ST.
2. Marketable natural gas is natural gas which meets specifications for end use whether it occurs naturally or through processing of raw natural gas to remove natural gas liquids.
3. Statistics Canada, *The Crude Petroleum and Natural Gas Industry*, Catalogue no. 26-213.

Association of Petroleum Producers is the data source.[1] The value of condensate[2] production is included with that for crude oil, while production values for pentanes-plus, propane, butane, ethane and sulphur are included in the value of natural gas production.

Capital expenditures - The following expenditures are considered part of the capital formation of the petroleum industry[3] in the SAA (and in the CSNA):

- exploration drilling;
- development drilling;
- production facilities;
- non-production facilities;
- enhanced recovery projects;
- natural gas processing plants;
- other expenditures.

Data for these expenditures are available from Statistics Canada.[4] Capital expenditure data for oil and gas producers are combined and must be split before being used in the SAA. In general, exploration expenditures are split according to each resource's share of the total depth of exploratory wells drilled in a year. Expenditures on development drilling, production facilities, and non-production facilities are split according to each resource's share of the total depth of development wells drilled in a year. Capital costs associated with enhanced recovery projects are attributed to crude oil production and those associated with natural gas process plants to natural gas production. More detailed information is reported in Born (1992) and McCulloch (1994).

No allowances are made for associated and solution natural gas in the allocation of the petroleum industry's exploration, development and operating costs. This is so because of precedents set by other researchers and because of limitations inherent in the expenditure data. A more detailed description of this rationale in presented in Born (1992).

The value of the produced capital stock used in the petroleum industry, and of the annual depreciation of that stock, are obtained from the Investment and Capital Stock Division of Statistics Canada.

Operating costs - The following expenses are included in the annual operating costs of the petroleum industry:

- geological and geophysical expenditures;
- field and well operations;
- natural gas process plant operating costs;
- other operating expenses.

Annual operating costs are allocated between crude oil and natural gas in proportion to each resource's share of total number of wells operating during the year. Data for these costs are taken from Statistics Canada sources.[5]

Coal

Reserves - Energy, Mines and Resources Canada (EMR; now known as Natural Resources Canada) evaluated coal reserves in each province in 1976, 1977, 1982 and 1985. With the exception of Alberta,[6] the physical coal accounts of the SAA are based on the recoverable reserve data published as a result of these evaluations. Estimation of coal reserves has not been undertaken in other years (except in Alberta), necessitating estimation of reserves in missing years. These estimates are made by reducing the previous year's reserves by the amount of coal extracted in years for which no reserve estimates are available.[7] The EMR data for 1976, 1977, 1982 and 1985 are used as benchmarks for these estimates since they are consistent and cover all coal-producing provinces. Reserve additions are calculated residually to correct for any discrepancies between opening and closing coal stocks that are not consistent with simple depletion. Often, adjustments of reserve additions are related to opening or closing of coal mines or a re-evaluation of the resource/reserve base.

Alberta has the largest share of Canada's coal reserves, about 60 percent of the total coal resource of immediate interest. Its reserves are also the best documented and measured. The Alberta Energy and Utilities Board reports the province's coal reserves as established reserves (rather than the recoverable reserves definition that is used in all other provinces). Alberta produces both bituminous and subbituminous coal. The physical account for Albertan coal is compiled by combining the Alberta Energy and Utilities Board's data for reserves and raw production for bituminous and subbituminous coal. For a more detailed description of coal reserve data, see Born *et al*. (1995).

Production, capital costs and operating costs - Data on quantity and value of production and operating costs (materials and supplies, fuel and electricity, and wages and salaries) for coal mines are available from Statistics Canada.[8] The value of the produced capital stock used in coal mines and the value of the annual depreciation of that stock, by province and coal type, are also available from Statistics Canada.[9]

1. Canadian Association of Petroleum Producers, *Statistical Yearbook*, Calgary.
2. Condensate is a mixture of pentanes and heavier hydrocarbons that is a by-product of crude oil extraction.
3. The petroleum industry should be taken in this context to include producers of crude oil, natural gas and crude bitumen. More specifically, it refers to industry group 071 (Crude Petroleum and Natural Gas Industries) of the *Standard Industrial Classification* (Statistics Canada, 1980).
4. Statistics Canada, *The Crude Petroleum and Natural Gas Industry*, Catalogue no. 26-213.
5. *Op. Cit.*
6. Data for Alberta are from Alberta Energy and Utilities Board, *Coal Reserves* and personal communication, Calgary.
7. Coal extraction data are from Statistics Canada, *Coal Mines,* Catalogue no. 26-206.
8. Statistics Canada, *Coal Mines*, Catalogue no. 26-206.
9. Statistics Canada, Investment and Capital Stock Division.

Metals

Reserves - Physical data for Canadian metal reserves are obtained from the Minerals and Metals Sector of Natural Resources Canada. These data are derived from information contained in annual and other corporate reports and from the responses of mining companies to the annual *Federal-Provincial Survey of Mines and Concentrators*. Reserves are reported as metal contained in ores that are classified by companies as “proven” and “probable” (or their equivalents) at producing mines and in deposits that are committed to production.

Reserves at most mines change slightly from year to year. It is usually a relatively small number of mining operations with large changes that affect the national trend in metal reserves.

Production, capital costs and operating costs - Data on quantity and value of production and operating costs for metal mines are available from Statistics Canada[1] and from the Minerals and Metals Policy Sector of Natural Resources Canada. The value of the produced capital stock used in coal mines and the value of the annual depreciation of that stock, by province and coal type, are also available from Statistics Canada.[2]

Classification of metal assets - The classification of metal assets used in the physical account is distinct from that in the monetary account. While the physical account records reserves on a metal-by-metal basis, the monetary account records reserves by mine type. The classification of mine used in the monetary account is identical to the classification of mining industries in the *Standard Industrial Classification* (Statistics Canada, 1980):

- gold mines;
- copper and copper-zinc mines;
- nickel-copper mines;
- silver-lead-zinc mines;
- molybdenum mines;
- uranium mines; and
- iron mines.

Classification by mine type rather than metal in the monetary account precludes arbitrary decisions regarding the share of mine development and exploitation costs attributable to each metal in polymetallic mines.[3]

1. Statistics Canada, *Metal Mines*, Catalogue no. 26-223.
2. Statistics Canada, Investment and Capital Stock Division.
3. A polymetallic mine is one at which more than one metal is mined.

3.3.5 Future directions for the Subsoil Asset Accounts

Future development of the SAA will be focused in several areas.

- High priority will be give to maintaining the current coverage of the accounts through annual updates of existing time series.
- The possibility of expanding the coverage of the accounts to include important subsoil assets not currently measured will be investigated. The most likely candidates for inclusion are gypsum and other industrial minerals.
- The linkage of the SAA with the MEFA (Chapter 4) will be strengthened so that the effect of recycling on the rate of depletion of metal reserves can be better studied.
- Finally, attention will be given to overcoming two shortcomings of the valuation methods currently employed in the MSAA. The first of these is the fact that monetary values are calculated for only a small part of Canada’s known subsoil asset reserves. The second is the tendency of the present value method to underestimate the value of subsoil assets.

3.4 Timber Asset Accounts

The **Timber Asset Accounts** comprise two accounts–one physical and one monetary–describing Canada’s timber assets. These accounts currently focus on the use of the forest for timber supply only. Other uses of the forest–for recreation or wildlife habitat for example–have not yet been considered. Timber supply has been chosen as the initial orientation of the account since this is the principal economic use of the forest in Canada.

As mentioned, the Timber Asset Accounts (TAA) comprise two accounts: the **Physical Timber Asset Account** (PTAA) and the **Monetary Timber Asset Account** (MTAA). Both accounts present annual time series data beginning in 1961 at the national and provincial/territorial levels. The PTAA provides year-end quantitative measures of Canada’s timber asset stocks and the impacts of harvesting and natural events on these stocks. The MTAA, being the value counterpart of the physical account, presents year-end value estimates for these same stocks. Although the stocks that are valued in the MTAA are the same as those described in physical terms in the PTAA, the stock changes shown in the physical account (growth, harvesting and natural losses) do not currently have monetary equivalents in the MTAA.

In Canada, forest quality (in the sense of timber productivity) and accessibility limit the portion of the forest that provides economic benefit. For this reason, only the accessible, timber-productive, nonreserved forestland is represented in the Timber Asset Accounts. This is the part of Canada's forestland where commercial timber production is viable; that is, the part on which harvesting is allowed and on which trees of commercially valuable species grow to a merchantable size in a reasonable length of time. This land accounted for approximately 144 million hectares, or 35 percent, of Canada's total forestland area of 417 million hectares in 1991 (Lowe, Power and Gray, 1994).

An important use of the Timber Asset Accounts is as the basis for the extension of the CNBSA to include estimates of the wealth associated with Canada's timber assets. As described in Section 3.1, this is achieved by extending the CNBSA to include monetary valuations of our timber asset stocks, following the recommendations of SNA93.

Although timber interests have justified most of Canada's traditional investment in forest management and data development, a change towards forest ecosystem management and forest health issues is generating a call for data on forest uses other than just timber supply. In response to this call, extension of the Timber Asset Accounts to cover other aspects of forestland will be undertaken as part of their future development (see Section 3.4.3 for further discussion).

3.4.1 Physical Timber Asset Account

The PTAA describes the timber volume, area, age-class and forest composition of forestland that meets the criteria for economic viability outlined above. The change in the stock of this land from year to year and the reasons for this change, such as growth, harvesting and natural loss, are presented.

The account is based on forest resource inventories produced by provincial and territorial forest departments/ministries. Although these inventories are conducted regularly, they often use different land bases from one period to the next. As a result, consistent stock data are not available as an annual time series. The provincial/territorial inventories are aggregated by the Canadian Forest Service of Natural Resources Canada to form *Canada's Forest Inventory*. This national inventory is available for both 1986 and 1991, although the differences between the 1986 and 1991 inventories do not reflect the actual changes that occurred between these points in time; the 1991 inventory is only a partial update of the 1986 inventory.

To overcome the lack of consistent, annual forest data, the stock/flow time series of the PTAA is estimated using a simulation model. Beginning with inventory data for a single year (1991), this model simulates the impact of growth, harvesting, natural loss and other changes to timber stocks over the period 1961 to 1990.[1] This type of simulation is similar to the timber supply analyses done by provincial forest managers.

Inventory data

Canada's Forest Inventory 1991 (CanFI91) was developed by Natural Resource Canada's Canadian Forest Service (Lowe, Power and Gray, 1994). This national inventory is produced with the co-operation of the provincial and territorial forest departments/ministries through the Canadian Forest Inventory Committee. Some of the forest terms used in this inventory are defined in Text Box 3.6.

The majority of the forest inventories that comprise CanFI91 are carried out to facilitate resource planning on geographical forest management units. These management unit inventories, known as forest resource inventories, are conducted at approximately 20-year intervals. This means that the average age of the forest inventories making up CanFI91 is close to 10 years.

For the purposes of the PTAA, CanFI91 data on forestland area and coniferous and broadleaved gross merchantable volume are used. These data cover eight provinces and one territory,[2] three forest types[3] and nine 20-year age classes. Age-class distributions are not available for Prince Edward Island, Manitoba and the Northwest Territories. Consequently, it is not possible to calibrate the simulation model for these regions.

The inventory area classification for 1991 is shown hierarchically in Figure 3.2 (page 44). Out of a total area of forestland in Canada of 417.6 million hectares, 244.6 million were timber productive and 169.7 million timber-unproductive. The timber-productive forestland is further broken down into reserved (9 million hectares) and nonreserved accessible (144.5 million hectares), nonreserved without access (89.0 million hectares) and unclassified (2.1 million hectares). The nonreserved accessible stock is again further subdivided into accessible nonreserved stocked and nonstocked timber-productive forestland areas; these are the forestland classes used in the simulation model. The nonreserved accessible forestland in Manitoba, Prince Edward Island and the Northwest Territories–which is excluded from the simulation–totals 7.8 million hectares, or just over 5 percent of the Canada total.

Simulation model structure

The PTAA uses a simulation model that is conceptually similar to a population model (Moll, 1992). It evolves an age-distributed stock of forestland area over time. The model represents eight provinces and one territory and distinguishes three forest types and 180 single-year age classes. The latter are derived from the nine 20-year age classes of CanFI91.

In the model, the processes of fire, mortality, harvesting, ageing and natural and artificial (planting) regeneration are

1. The simulation model covers the years 1961 to 1990 inclusive. Since closing stocks in 1990 represent opening stocks in 1991 however, the stock variables in the model are presented as opening stocks for the period 1961 to 1991.

2. Newfoundland, Nova Scotia, New Brunswick, Quebec, Ontario, Saskatchewan, Alberta, British Columbia and Yukon.

3. Softwood, mixedwood and hardwood.

Text Box 3.6

Glossary of forest terms

Accessibility of forestland*: An assessment of the effect that availability of access, topography and soil have upon the cost of harvesting a given timber stand.

Age class*: Any interval into which the age range of trees, forests, stands or forest types is divided for classification and use.

Annual allowable cut*: The volume of wood which may be harvested, under management, during a given year.

Cutover*: An area of forest from which some or all of the timber has recently been cut.

Even-aged: A situation where relatively small differences in age exist between individual trees. The differences in age permitted are usually 10 to 20 years; if the stand will not be harvested until it is 100 to 200 years old, large differences of up to 25 percent of the rotation age may be allowed.

Forest health: A condition of forest ecosystems that sustains their complexity while providing for human needs (O'Laughlin, 1996).

Forestland*: Land primarily intended for growing, or currently supporting forest growth. Includes land not now forested. For example: clearcuts; northern lands that are forested but not intended for timber use; and plantations.

Forest management unit*: An area of forestland managed as a unit for fiber production and other renewable resources. This unit can be the entire province or territory, a provincial forest management subdivision, or an industrial timber limit.

Forest resource inventory*: A survey of a forest area to determine such data as area, condition, timber volume and species for purposes such as planning, purchase, evaluation, management or harvesting.

Forest storey*: A horizontal stratum or layer in a plant community, appearing in forests as one or more canopies. A forest having two storeys (the overstorey and the understorey) is called two storeyed.

Forest type*: A group of forested areas or stands of similar composition that differentiates it from other groups. Forest types are usually separated and identified by species compositions and often by height and crown closure classes as well.

Growing stock*: The sum (by number, basal area or volume) of trees in a forest, or in a specified part of it.

Growth (increment)*: The increase in diameter, basal area, height, volume, quality, or value of individual trees or stands during a given period.

Hardwood forest type*: Trees that lose their leaves in autumn. They belong to the botanical group Angiospermae.

Mixedwood forest type*: Trees that belong to either of the botanical groups Gymnospermae or Angiospermae that are substantially intermingled in stands.

Mortality of forests*: Death or destruction of forest trees as a result of competition, disease, insect damage, drought, wind, fire, and other factors, excluding harvesting.

Nonreserved forestland*: Forestland that, by law or policy, is available for the harvesting of forest crops.

Nonstocked forestland*: Productive forestland that lacks trees completely or that is so deficient in trees, either young or old, that at the end of one rotation, the residual stand of merchantable tree species, if any, will be insufficient to allow utilization in an economic operation.

Regeneration*: The renewal of a forest crop by natural or artificial means. Also the new crop obtained. The new crop is generally less than 1.3 metres high.

Reserved forestland*: Forestland that, by law or policy, is not available for the harvesting of forest crops.

Rotation*:** The period of years required to establish and grow even-aged timber crops to a specified condition of maturity.

Roundwood*: Sections of tree stems with or without bark. May include logs, bolts, posts and pilings.

Silviculture*: Silviculture is the theory and practice of controlling the establishment, composition and growth of forests. It is applied forest ecology directed at the protection and enhancement of wildlife, water, soil, and timber resources (Wenger, 1984).

Softwood forest type*: Cone-bearing trees with needles or scale-like leaves. They belong to the botanical group Gymnospermae

Text Box 3.6 (concluded)

Glossary of forest terms

Species group: Grouping by which volumes are reported. **Coniferous** group includes volume from black spruce, other spruce, white pine, jack and lodgepole pine, other pine, fir, hemlock, douglas-fir, larch, cedar and other conifers. **Broadleaved** group includes volume from trembling aspen, other poplar, yellow birch, other birch, sugar maple, other maple, and other broadleaved species.

Stocked forestland*: Land supporting tree growth. In this context growth includes seedlings and saplings.

Succession: Changes in the species composition of an ecosystem over time, often in a predictable order.

Timber productive forestland*: Forestland that is capable of producing a merchantable stand within a reasonable length of time.

Timber-unproductive forestland*: Forestland that is incapable of producing a merchantable stand within a reasonable length of time. Includes muskeg, rock, barrens, marshes, meadows and other timber-unproductive areas within a forest.

Unclassified: Most inventory categories include this class to cater to source inventories where information is not available and must be handled as missing values.

Volume: The gross merchantable pulpwood standing volume of stocked timber-productive forest is reported by species group in cubic metres or cubic metres per hectare. Gross volume makes no allowance for defects such as decay (except in British Columbia where net volumes are reported). Merchantable volume is main stem under bark excluding stump and top allowances. Pulpwood volume is of dimensions large enough to be considered as pulpwood in local practice. It includes volumes that meet higher dimensional standards (sawwood).

Yield*: Growth or increment accumulated by trees at specific ages expressed by volume or weight to defined merchantable standards.

Yield table*: A summary table showing for stands (usually even-aged) of one or more species on different site qualities, characteristics (volume per hectare) at different ages of the stand. An empirical yield table is one prepared for actual average stand conditions.

Note:
Terms marked with an asterisk (*) are from Haddon (1988).

integrated with forest inventory data over the time period 1961 to 1990. As a first step in simulating the evolution of the forest, a 1961 age-class distribution is estimated by running a version of the model backwards. Using this estimated age-class distribution as the initial condition for 1961, the model is then run forwards to meet the desired 1991 data points.

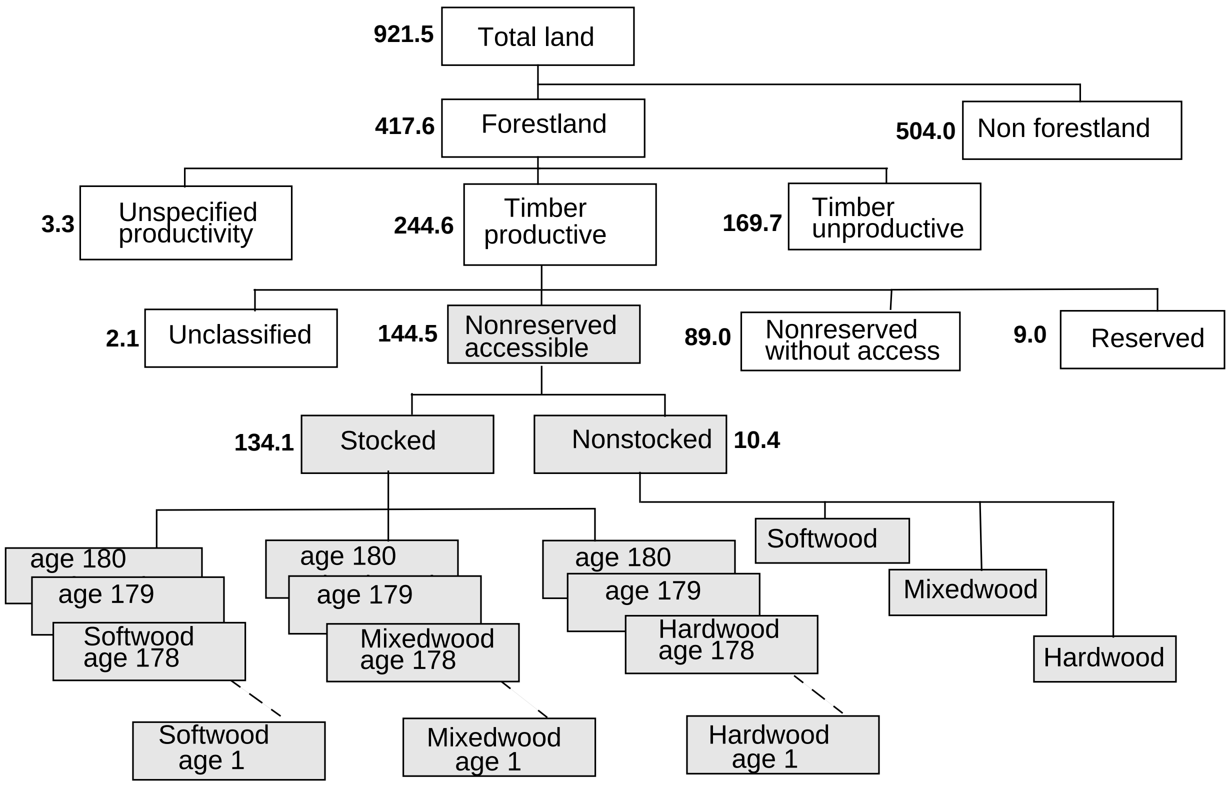
The following are the factors giving rise to changes in the simulated timber asset stock over time:

- catastrophic forest fires;
- natural mortality;
- coniferous volume harvested;
- broadleaved volume harvested;
- volume lost to logging roads;
- ageing;
- natural regeneration of burned areas;
- natural regeneration after mortality; and
- artificial and natural regeneration of harvested and nonstocked forestland.

Figure 3.3 (page 45) is a structural diagram representation (Gault *et al.*, 1987) of the main inputs and outputs of the fire, mortality, harvesting, ageing and regeneration processes. The order in which the calculations are performed in the model during one period is shown from top to bottom.

First, the stocked forestland at the start of a period is adjusted for loss due to fires and natural mortality (Block 1). The surviving stocked forestland is input to the harvesting calculation (Block 2) where the annual roundwood volume of production (cubic metres of timber) is translated into hectares to provide an estimate of the area harvested for use in the physical account. In Block 3, forest that burned or died from natural causes is regenerated naturally. Also, in this block newly harvested area (cutover) regenerates either by planting or natural regeneration. The regeneration process is completed by apportioning nonstocked forestland to either natural or artificial regeneration. Finally, the stocked forestland is then aged by shifting area from each age class to the next oldest age class. The year index is incremented and the calculations are repeated for as many years as there are in the simulation time period. The processes of fire, mortality, harvesting, ageing and regeneration are described in more detail in the following sections.

Figure 3.2
Area Classification of CanFI91



Notes:
Areas are measured in millions of hectares.
Shaded areas represent data used in the PTAA.
Source:
Lowe, Power and Gray, 1994.

Block 1: Forest fires and natural mortality

The first block in Figure 3.3 represents the reductions of stocked productive forestland due to fire and natural mortality in a period. Forestland is updated for fire by decreasing the inventory using data describing area burned by province/territory for the years 1961 to 1991 (Ramsey and Higgins, 1981; 1982; 1986; 1991; and 1992). The annual fire losses over this time period vary considerably. Fire data are not available on a forest type or age-specific basis. To deal with this shortcoming in the data, fire rates are calculated for each year and province/territory as a percentage of the total forestland area in each province/territory. These rates are then applied uniformly across each age class and forest type in the forestland stock. The area burned, stratified by age class and forest type, is subtracted from the stock. Then the area burned is summarized by forest type and regenerated in age class 1 at the start of the subsequent year for the same forest type.

The surviving stocked forestland is subject to a mortality process where a proportion (10 percent) of the area of forest in the ten oldest age classes (171-180 years) is assumed to die naturally. This area is removed from the stocked forestland age classes. The total forestland area that dies in a period is input to Block 3 where it is regenerated. The updated stocked forestland is then input to the harvesting procedure described in the next section.

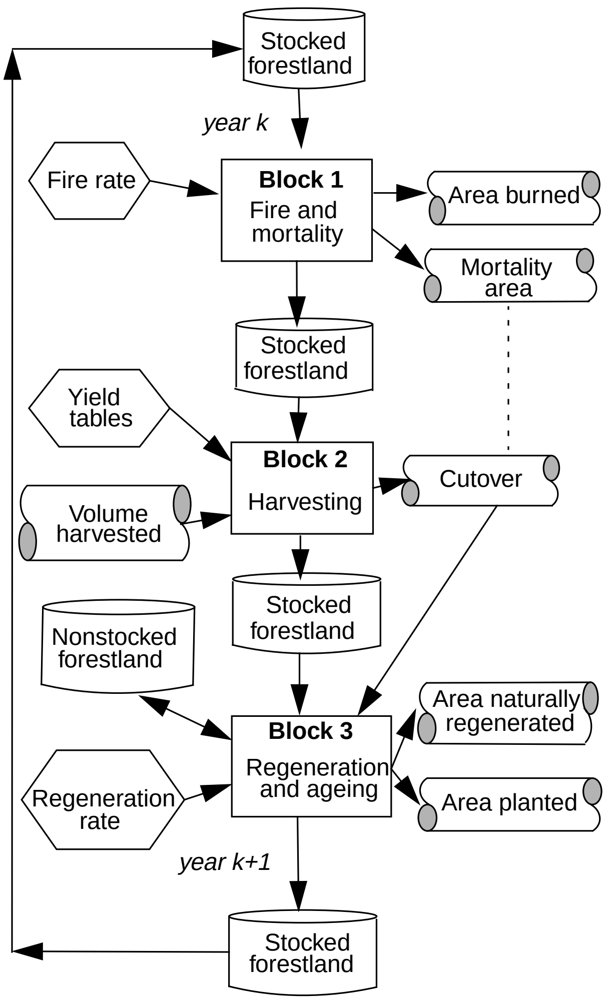
Block 2: Harvesting

Block 2 of Figure 3.3 represents how the historical production of roundwood volume[1] is translated into area harvested so that the forestland stock can be adjusted each year. Both coniferous and broadleaved roundwood volume may be harvested from each of the three forest types (softwood, mixedwood and hardwood stands).

In the simulation model it is assumed that 75 percent of the coniferous volume is harvested from softwood and 25 percent from mixedwood stands.[2] All the broadleaved volume is assumed to be met by harvesting from the hardwood forest type.

1. Statistics Canada, *Logging Industry*, Catalogue no. 25-201.
2. These values are judged reasonable by observing the species-specific volume in CanFI91.

Figure 3.3
Time Loop Structure



The first step in the harvesting block is calculation of the potential volume available for harvesting coniferous timber in the softwood and mixedwood forest types. This is calculated by multiplying the unit volume per hectare yield[1] for coniferous species by the forestland area and summing over the allowable age classes. The latter are the age classes in which harvesting may occur and are called the "limits of operability." This is the period in a stand's development when the volume is sufficient for profitable harvesting. For coniferous species the limits of operability are 80 to 180 years.

Similarly, the potential broadleaved volume is calculated by multiplying the forestland area in hardwood forest type by the unit volume per hectare for broadleaved species in the hardwood forest type and summing over the age classes 70 to 180. Harvesting of trees that have reached 70 years of age, a lower limit of operability than for coniferous species, is allowed.

Next the ratio of roundwood harvested to the volume that could potentially be harvested is calculated for both species types. This proportion (harvest ratio) is used to determine how much forest must be cut to satisfy the actual production in each year. In other words, the harvest is allocated across age classes in proportion to the total potential volume in each forest type.

An allowance of three percent of annual area harvested is made for the construction of roads in the forest. Stocked productive forestland is therefore reduced by three percent of the area harvested each year, since newly created roads are not regenerated as stocked forestland.

The area harvested is summarized each year by forest type. This area is then passed to block 3 of the model, which represents the regeneration process.

Block 3: Ageing and regeneration after fire and mortality

Ageing of the forest and natural regeneration after both fire and other natural causes of mortality are represented in the last block of Figure 3.3. It is assumed that regeneration occurs immediately after both fire and natural mortality.

Ageing of the forest, which occurs at this stage in the simulation, is represented by a simple update procedure. That is, all area in each class from 1 through 178 is shifted to the next oldest age class (i.e. ages 2 through 179). The oldest age class (i.e. 180 years and older) is updated by accumulating the area in age class 179 as well as the surviving area in age class 180.

Natural regeneration of burned land is represented by updating the first age class (regeneration class) of stocked forestland at the start of the next simulation year. First the area burned is summarized by forest type and age class in each year. Then the stocked forestland in age class 1 for year *k+1* is updated by the area burned during year *k*. It is assumed that the area regenerates to the same forest type after a burn.

Forestland affected by natural mortality other than fire regenerates in the following way. Rather than regenerating this area in age class 1 at the start of the next period, this area is distributed amongst age classes 2 to 179 according to the current age and forest type distribution. The reasoning here is that stand mortality is not an abrupt process; trees do not die off as soon as they reach 171 years. Rather, mortality in the stand and regeneration in the form of an understorey is always present.

Since the single-year age-class distribution used in the model is derived from the aggregate 20-year age-class distribution of CanFI91, discontinuities are created in the annual mortality function. In order to smooth the mortality function, natural mortality is approximated by assuming that a proportion of the area in the ten oldest age classes (171-180 years) dies in each period and is subsequently regen-

1. Yield tables are calculated from CanFI91 by dividing the gross merchantable timber volume by age by the forestland area by age. This gives an empirical estimate of yield, or gross merchantable volume per hectare, by age for two species groups (coniferous and broadleaved) in three forest types.

Table 3.8
Artificial Regeneration Transitions

	Softwood	Mixedwood	Hardwood
Softwood	0.440	0.397	0.163
Mixedwood	0.194	0.598	0.208
Hardwood	0.150	0.620	0.230

Source:
Hearnden, Millson and Wilson, 1992.

Table 3.9
Natural Regeneration Transitions

	Softwood	Mixedwood	Hardwood
Softwood	0.43	0.411	0.159
Mixedwood	0.21	0.580	0.210
Hardwood	0.07	0.360	0.570

Source:
Hearnden, Millson and Wilson, 1992.

erated. This has the effect of eliminating discontinuities in the model's response to the assumed single-year age-class distribution.

Block 3 (continued): Regeneration of cutover and nonstocked forestland

Natural and artificial regeneration of the cutover and previously nonstocked forestland occur next in the model. Areas that naturally regenerate are distinguished from those that are artificially regenerated by multiplying the area to be regenerated by an assumed natural regeneration share of 50 percent. The regeneration rates for both the cutover and previously nonstocked forestland determine how fast these areas regenerate. The annual regeneration rate for recently harvested forestland is assumed to be 99 percent and that for nonstocked 0.5 percent. In other words, 0.5 percent of nonstocked land regenerates each year, whereas 99 percent of cutover area regenerates each year.

Succession to different species types during regeneration is calculated based on the probability of transition to different forest types after harvest and planting. Data on regeneration after harvest and planting are available for Ontario (Hearnden, Millson and Wilson, 1992). These are incorporated into two regeneration transition matrices, one for artificial regeneration (planting) and one for natural regeneration (tables 3.8 and 3.9 respectively). The regeneration transition matrices are dimensioned three forest types by three forest types indicating by row the propensity of regenerating from one forest type to another.

The nonstocked forestland at the beginning of period *k+1* is updated by including the proportion of the previous period's cutover that will not have regenerated plus the surviving nonstocked forestland from the end of the previous year *k.* Finally, stocked forestland is updated at the beginning of year *k+1* in age class 1 for natural and artificial regeneration of harvested and nonstocked forestland during period *k*.

Results of the simulation model

What is most evident from the simulation exercise is the discrepancy between the simulated age-class distribution of the stocked forestland in 1991 (Figure 3.4) and that given by the CanFI91 (Figure 3.5). Reductions in timber stocks due to natural losses and harvesting during the simulation period should, as suggested by the simulation, show up as regeneration in the first 30 year age classes of CanFI91. As can be seen in Figure 3.5, the inventory does not account for this regeneration. It could be argued that the PTAA is a method for updating CanFI91, since it reconciles the historical disturbances to timber stocks, such as fire and harvesting, which we know have occurred.

The problems associated with aggregation of provincial inventories (which were never designed to be used for national or provincial summaries) show clearly that a new national and provincial inventory method is needed. In a recent discussion paper (Magnussen, Bonnor and Sterner, 1996), several national systems for monitoring the forest resource are proposed. These systems might involve the timely collection of data from permanent/temporary inventory plots or the sampling of units located in a systematic way across Canada.

Presentation of the PTAA

Like the Subsoil Asset Accounts, the Physical Timber Asset Account is presented as a reconciliation account. It provides annual opening and closing estimates of standing timber stocks and timber-productive land area, plus the changes in the volume of these stocks due to harvesting and natural events. Table 3.10 shows the layout of the PTAA reconciliation account.

Table 3.10
Physical Timber Reconciliation Account

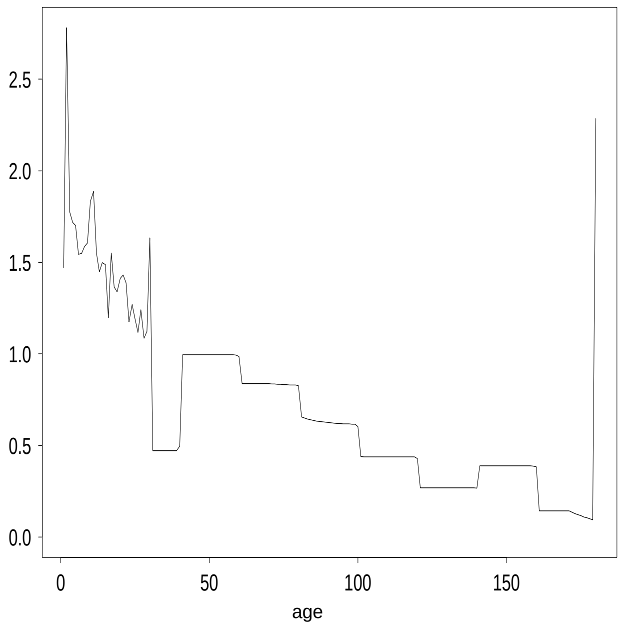
[1] Opening stock
[2] Natural growth
[3] Harvest
[4] Mortality
[5] Fire loss
[6] Loss due to roads
[7] Closing stock [1 + 2 - 3 - 4 - 5 - 6]

3.4.2 Monetary Timber Asset Account

The Monetary Timber Asset Account (MTAA) is the value counterpart of the PTAA, with two differences. One is the aforementioned fact that the MTAA does not show values for the annual changes in timber stocks resulting from natural losses and harvesting. The other is that the MTAA shows stock value estimates for all provinces and territories.[1]

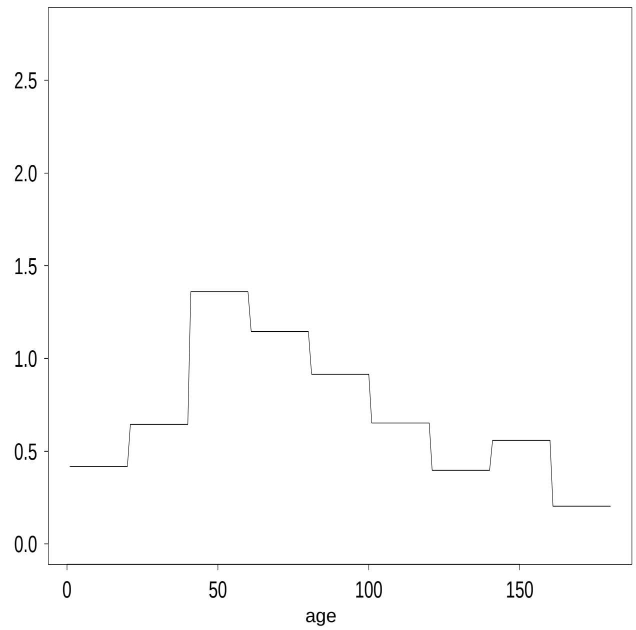
The MTAA presents annual estimates of the value of standing timber on Canada's timber-productive, stocked, acces-

Figure 3.4
Simulated Age-class Structure, 1991



Source:
Statistics Canada, National Accounts and Environment Division.

Figure 3.5
CanFI91 Age-class Structure



Source:
Lowe, Power and Gray, 1994.

sible forestland. Estimates covering the period 1961-1995 are currently presented for both the nation and for each province and territory. Following the recommendations of the SNA93, the national-level value estimates are to be included in the CNBSA as part of Canada's wealth.

To be comparable with other tangible produced and non-produced assets entered on the national balance sheet, timber assets are recorded at their market value. This is the price that would be paid for them if they were sold in a competitive public market. Measuring the market value of timber resources in Canada is problematic however. More than 84 percent of the forestland that is considered an economic asset in Canada is government owned and transactions in timberland or cutting rights are rare. As a result, the market value of timber assets must be estimated using indirect methods.

The estimates of timber asset values in the MTAA are based on the concept of resource rent. As described in Section 3.2.1, resource rent is equivalent to the revenue generated from resource extraction less all costs involved in bringing the resource to market. In the MTAA, an estimate of annual timber rent is calculated by subtracting all current and capital costs incurred by forest product industries in felling, transporting and processing timber from the revenue earned from the sale of forest products. Annual forest management costs incurred by governments in maintaining the timber resource are also deducted in the calculation.

The resource rent so estimated includes both the rent associated with timber and that associated with the land dedicated to timber production. If an estimate of the holding cost of land was available, it could be deducted from the rent estimate to leave a residual value for timber alone; however, no such estimate is available. Since the rent includes both timber and the associated land, the resource asset might be more appropriately thought of as timberland, or forestland for timber production, rather than timber. For the sake of simplicity, the resource is referred to simply as timber in the MTAA.

Timber resource rent so calculated represents the value of the timber harvested in a single year only. To estimate the value associated with the *total* stock of Canadian timber, the present value of the stream of rent assumed to be generated from future timber harvests is estimated. In this calculation, it is assumed that both the rent value of recent harvests and the volume harvested are applicable to the remaining stock. The stock is then valued as the present value of an infinite series of constant annual rent returns.

The methods used in the MTAA to estimate the rent associated with timber assets and the methods used to convert rent into overall stock value are explained in more detail in the following two sections. Many of the issues surrounding these methods have already been discussed in Section 3.2.1 and are not given detailed coverage in this section. Only the application of the methods to the valuation of timber assets is discussed at length here. For the sake of con-

1. Recall that the PTAA currently excludes Prince Edward Island, Manitoba and the Northwest Territories because of data gaps in CanFI91. Because the MTAA rests on different data sources than the PTAA, estimates of the timber asset value for these provinces are available in the MTAA.

venience, Text Box 3.7 repeats the algebraic descriptions of the present value methods for timber asset valuation presented earlier in Text Box 3.4.

Calculation of timber rent

Ideally, the rent attributed to timber would be based on observed market transactions in timber assets. Most of Canada's forestland is government owned however, and there are few observable market transactions in timberland or cutting rights. Rather than selling cutting rights, provincial and territorial governments enter into management agreements with producers of forest products. Under these agreements, maximum allowable harvest levels–known as annual allowable cuts–are set based on an assessment of long-run sustainable timber yield. The governments receive revenue in the form of area charges and stumpage fees in return for wood supply and management services. Since stumpage fees are set by the government rather than determined by public auction,[1] it is difficult to know how closely they reflect the market value (and therefore rent) of the timber. Thus, stumpage fees cannot be used as a proxy for timber rent and an indirect estimate of rent is required.

Timber rent in the MTAA is estimated from historical data on annual production by forest product industries in each province. The estimate is based on harvesting that occurred on the timber-productive land base using the available production capacity in period. The industry group considered in the calculation comprises both the logging industry and the secondary wood processing industries that sell their output in public markets. These secondary industries are the pulp and paper industry, the veneer and plywood industry, and the sawmilling and planing industry.[2]

Costs incurred by these industries in felling, transporting and processing timber, plus governments' costs associated with maintaining timber assets,[3] are subtracted from the value of the forest products produced. All current, or operating, costs (labour and fuel for example) are deducted, with the exception of stumpage fees paid; these are rightly considered a component of the rent residual. An estimate of the cost of produced capital used in the harvesting activity is also deducted. In fact, as discussed in Section 3.2.1, two different estimates of the cost of capital are deducted (Eq. 3.2 and Eq. 3.3 in Text Box 3.7), yielding an upper and lower bound on timber rent in each year.

Subject as the forest product industries are to a pronounced business cycle, changing prices and production volumes cause annual timber rent to fluctuate significantly from one period to the next. To smooth these fluctuations, the rent estimate used in calculating timber asset stock values is actually a moving average of the previous five years' rent.

Text Box 3.7

Methods of Valuing Timber Asset Stocks

Estimation of resource rent

$RR_I = TR - C - (r_i K + \delta)$ (lower bound) Eq. 3.2

$RR_{II} = TR - C - \delta$ (upper bound) Eq. 3.3

1. Present value I (positive return to produced capital)[1]

$PV_I = RR_I / r_g$ Eq. 3.7

2. Present value II (zero return to produced capital)

$PV_{II} = RR_{II} / r_g$ Eq. 3.8

Definition of symbols:

- δ = depreciation of the produced capital stock
- C = annual non-capital extraction costs, including fuel, electricity, materials, supplies and wages
- K = produced capital stock valued at replacement cost
- PV = present value of the resource stock
- RR = annual resource rent
- TR = total annual revenue from resource extraction
- r_g = real provincial government bond rate
- r_i = nominal long-term industrial bond rate

Note:
1. The expression for calculating the present value of an income stream simplifies to (annual income)/(interest rate) when the time period is infinite.

Calculation of timber asset stock value

The estimate of the value of Canada's timber asset stocks in the MTAA is based on the discounted present value of an infinite series of the average annual rent estimated for each year (as described above). Two present value calculations are used (Eq. 3.7 and Eq. 3.8 in Text Box 3.7), one for each of the methods of estimating timber rent.

1. The market value of timber determined by public auction would be the highest bid based on buyers' calculations of "stumpage value", the difference between the eventual selling price of the timber and the cost of felling and bringing it to market. The term stumpage value means, literally, the value of timber "on the stump" before industrial intervention.
2. Grouping of the logging and secondary wood processing industries is necessary because many logging establishments are part of integrated firms. These establishments do not actually sell timber to their parent mills, so that the "selling prices" they report do not necessarily reflect market prices for timber. If their reported selling price is low *vis à vis* the true market price, part of the timber rent is, in effect, shifted to the "buyer" of the timber. A rent calculation based on the logging industry alone would be understated in this case. Similarly, a high reported price would overstate the timber rent. Grouping the logging industry with the secondary wood processing industries avoids the problem of over- or understating the resource rent due to vertical integration in the industry.
3. These costs include expenditures on silviculture, the provision and maintenance of access roads, and protection from fire and insect damage. Although many of these costs are capital expenditures, because of a lack of detailed data they are all treated as current expenditures; that is, they are deducted in the year in which they are incurred, rather than amortized over a longer time period.

The assumption implicit in these calculations is that the harvest volume on which the rent is based is indefinitely sustainable. The validity of this assumption has not been verified by a simulation of future harvests.[1] If harvests were to be reduced in a not too distant future, the estimated stock values recorded in the MTAA would be too high.[2] The nature of the present value calculation is such that rents from harvests in the distant future are discounted to very low present values. Therefore, the possibility of reduced harvests in the distant future has little or no effect on the estimated stock value.

As mentioned in Section 3.2.1, the position taken in the NRSA is that the discount rate used in estimating resource asset stock values (r_g) should reflect a government (or social) risk-free time preference. The rate used, four percent, is the approximate average real interest rate on provincial government bonds during the period since 1961. A real rate is used because there is no need to account for inflation; constant future prices and costs are assumed.

Net price valuation

Aside from the methods just described, a number of alternative approaches exist for estimating the value of timber stocks. One of the simplest is to apply the value of rent per unit of volume harvested to the volume of standing timber. This method, which is analogous to the “net price” valuation of subsoil assets, is inappropriate for Canada’s timber stocks.

First, a large part of Canada’s timber is mature forest that will be harvested in the (sometimes very distant) future. The value of this timber should be discounted to its present value. A “net price” approach is more appropriately used for a growing forest, especially a managed forest with a similar number of trees in each age class. In such a forest, the undiscounted value of the volume estimated using a net price is an approximation of the present value of the timber resource. The current value of a young tree approximates the discounted present value of the larger volume that will be harvested in the future.

1. It is possible to simulate the future growth and harvest of a province's total stock of timber. Such a simulation could be used to determine whether there will be sufficient timber in the future to maintain the current annual harvest volume indefinitely. If the harvest volume is shown to be sustainable, the value of the timber resource is appropriately the present value of an infinite series of the current annual rent. The value could be adjusted downward if the simulation showed either temporary or permanent shortfalls in supply. Such a simulation would have to be done with data for small areas rather than for an entire province, since the age at which timber will be harvested and the potential supply of timber varies among the different forest management units within a province.
2. Canada's timber resource is partly mature, or virgin, forest recently made accessible and partly forest growing on previously harvested land. Forest recently made accessible is mainly mature timber, but also includes growing forest that has regenerated after fire. The harvest of this mature timber will continue for some time. The eventual transition from virgin to managed forest will imply a reduction in harvest volume since trees are harvested at an earlier age in a managed forest. Offsetting this effect might be enhanced future harvests due to improved silviculture and tending of the forest.

A second reason for not directly valuing standing timber volume is the importance of fire loss. This method requires a difficult adjustment to the volume for each tree’s probability of surviving to harvest age.

Data sources and methods

Timber and forest product production is based on the value of shipments and inventory changes taken from Statistics Canada publications.[3] The value of wood cut by consumers for own consumption (primarily firewood and some sawn wood) is not estimated. Statistics on operating costs are also from Statistics Canada.[4]

Capital costs include both depreciation (δ) and a return to capital ($r_i K$). Depreciation and end-of-year capital stock values (K) by industry are prepared by Statistics Canada's Investment and Capital Stock Division. Capital stock is valued at replacement cost and depreciation is calculated on a straight line basis. The cost of financing capital (r_i) is a nominal, average corporate long-term bond rate,[5] which is applied to the value of the capital stock to estimate the return to capital.

Data representing forest management expenditures by provincial and territorial governments are published in the *Compendium of Canadian Forestry Statistics* (Canadian Council of Forest Ministers, 1993). These data apply to more than just the timber-producing part of the forest, so allocation of expenditures according to purpose is required. This is accomplished using the results of a study of forest protection and renewal done for the Ontario Ministry of Natural Resources (Ontario Ministry of Natural Resources, 1993b). Data on forest management expenditures are available beginning in 1977 only; expenditures for earlier years are backcasted based on these data. Fire control expenditures are backcasted using historical fire loss data from the PTAA. Other expenditures are backcasted using timber harvest volumes, also from the PTAA.

3.4.3 Future directions for the Timber Asset Accounts

At a minimum, future development of the Timber Asset Accounts will see the existing accounts maintained with up-to-date estimates of the volume, area and value of standing timber. Beyond the maintenance of the *status quo*, investigation of several ways in which the scope of the accounts might be expanded is planned.

As mentioned earlier, a change towards forest ecosystem management and forest health issues is generating a de-

3. Statistics Canada, *Logging Industry,* Catalogue no. 25-201.
Statistics Canada, *Sawmilling and Planing*, Catalogue no. 35-204.
Statistics Canada, *Pulp and Paper Mills*, Catalogue no. 36-204.
4. Statistics Canada*, Logging Industry,* Catalogue no. 25-201.
Statistics Canada, *Canadian Forestry Statistics,* Catalogue no. 25-202.
5. Bank of Canada, *Bank of Canada Review*, Table F1, Financial Market Statistics.

mand for data on forest uses other than timber supply.[1] Future editions of the Timber Asset Accounts could cover economic uses of the forest beyond timber supply and uses or benefits that are outside the domain of market-based activity.

With respect to expanded measures of economic value, the development of estimates of the value of parkland and the recreational use of forestland is a priority for future research.

Uses and benefits of the forest outside the domain of market-based economic activity include direct human uses such as harvesting forest products for direct consumption, non-market recreation and aesthetic appreciation. Indirect-use benefits of the forest, such as carbon fixation, oxygen production, the prevention of soil erosion and water purification/storage, are also relevant. As essential inputs into human well-being, these natural functions can be seen to have great value, but as “free” services of nature they have market prices of zero.

Expansion of the accounts in the above directions will require the development of classifications as well as valuation methodologies. The SNA93 classification of natural resources as economic assets contains three categories relevant to forest: timber, timberland and parkland, and other recreational land. This classification cannot be easily followed in the Canadian context for two reasons. First, as noted above, the value of timber and timberland cannot be easily separated. Second, there is some overlap between uses of the forest; logging is permitted on some parkland and forest used for timber production is available for other uses at least part of the time. A classification based on uses of the forest such as timber harvesting, harvesting of other forest products, recreation and other uses will be explored. The use of willingness-to-pay and other methods of non-market valuation will be considered in development of estimates of monetary value for non-timber economic, and non-market, benefits.

The timber resource that is valued in the MTAA currently is the accessible timberland at each year-end. Although Canadian timberland area has changed since 1961,[2] these changes are not currently covered in the PTAA due to a lack of data. The changes can be grouped into three major classes: expansion of the accessible forest landbase; changes in land use; and the protection of forest from logging activity (an increase in “reserved” forest). Data for these physical changes will be incorporated into the Timber Asset Accounts in the future, and estimates of the effect of these changes on the value of the timber resource will be made. The value estimated will be that of the timberland area gained or lost.

As well as the value associated with changing timberland areas, the value of changes in timber volume on the existing land base remains to be incorporated into the MTAA. These changes are the result of growth, harvesting and natural losses due to fire, insects, disease or wind.[3] Although they are currently measured in the PTAA, no attempt has yet been made to calculate the corresponding changes in timber asset value. The effects of growth, harvest and natural losses during a year may alter the age structure of the forest sufficiently to affect the volume harvested at some future date. Estimating the associated lost volume and value with any accuracy requires very detailed data that are not currently available.

3.5 Land Account

Information on Canada’s land resource is scarce at the national level, and the information that is available is often outdated and highly generalized. The purpose of the Land Account is to provide Canadians with an improved set of information to describe this resource.

Historically, information on land has been used to track ownership, develop local land-use plans and evaluate resource potential. Land-use conflicts in the past led to the need for land-use planning, which in turn fuelled the demand for information to address existing issues and avoid future conflicts. More recent environmental and resource concerns require even more extensive and detailed land data than those called for historically.

The Federal/Provincial Committee on Land Use sponsored a forum in 1995 to discuss land-use issues (Federal/Provincial Committee on Land Use, 1996). Priority issues were determined by consensus and classified according to four key land-use categories: agriculture, forestry, shore zone/coastal zone, and urban. The detailed issues discussed at the meeting are summarised in Text Box 3.8. Besides providing a useful overview of some important land-use issues, the committee emphasized the lack of suitable data and indicators in each of the priority areas it identified. Inadequate valuation of land resources was noted as a shortcoming in all areas. The committee also highlighted shore/coastal zone issues, which are generally not considered in land-use discussions. The Land Account provides improved information to address all of these issues.

One of the confounding factors in land policy, and therefore in the supporting statistics, is that two or more jurisdictions

1. One example of the impact of this change is found in the attempts made to remove the “timber bias” from the forest terminology in CanFI91. For example, the former forest characterisations “productive” and “unproductive” have been replaced with “timber productive” and “timber unproductive” to avoid statements such as “almost half of Canada’s forests are unproductive.”
2. Technological changes in harvesting and wood processing techniques mean that an increasing amount of the standing volume can today be harvested and used in forest products. New uses have been found for some species, making them commercially valuable when they were not before. Previously inaccessible areas have been opened with road building, and part of the existing area has been restricted to maintain habitat or prevent erosion. Finally, the construction of mills has made previously uneconomic forest in their vicinity commercially viable.
3. A decrease in timber asset value due to acid rain damage would also be included.

Text Box 3.8
Federal/Provincial Land-use Issues

Agriculture:

- degradation of agri-ecological resources through agricultural practices; on and off-farm effects;
- lack of an agricultural land policy;
- loss of the agricultural land base;
- competing uses on rural lands.

Forestry:

- multiple use conflicts;
- impact of forest management practices on production and the environment;
- inclusion of aboriginal needs and interests in forest management.

Shore zone/coastal zone:

- impact of land sources of pollution;
- competing use of shore areas (such as aquaculture and recreation);
- restriction of public access to the shore.

Urban:

- planning and financing of hard services and infrastructure;
- protection of water supplies;
- impact of urban related development in rural areas (such as urban sprawl and ribbon development).

Issues common to all categories:

- present governance systems unable to identify and solve problems (or take advantage of opportunities);
- lack of current data and measurable indicators of land use patterns and change;
- inadequate valuation of common resources; and
- lack of integrated planning and communication.

(federal, provincial, regional, municipal) can influence the use of a given tract of land. For example, many provinces and territories have their own land-use classifications. Additionally, much land-tenure and land-use information resides within registry offices in thousands of municipalities across the country. The Land Account addresses these difficulties by harmonizing the land information now collected by numerous jurisdictions for many different purposes. The classifications it employs permit the use and comparison of land information from a variety of sources. This allows, for example, the evaluation of the benefits and costs of converting agricultural land to urban land. The results of such evaluations could be used to address issues such as long-term sustainability and biodiversity.

The macro land-use classifications used in the Land Account match the scope of the national-level land information currently available in Canada. More detailed land-use and land-cover classifications have been developed by the Government of Canada through the *Canada Land Use Monitoring Program* (CLUMP). These classifications conform with international standards such as the *Standard International Classification of Land Use* (United Nations Statistical Commission and Economic Commission for Europe, 1985). As the Land Account develops, these detailed classifications will take the place of the simpler classifications currently used.

3.5.1 Uses

The Land Account provides detailed time-series information on the use of Canada's land resource. This information is of central importance in responding to many questions.

- What is the distribution and quality of our land?
- How is land used and what are the trends in this use?
- Is land use becoming more or less sustainable?
- Is the environmental stress associated with land use increasing or declining?
- What is the monetary value of our land and is this value increasing or declining?

With respect to this last question, a specific role of the Land Account is to provide extended estimates of the value of Canada's land for inclusion on the CNBSA. As described earlier with respect to sub-soil and timber resources, the SNA93 recommends the inclusion of natural resource assets in national balance sheet accounts. Much of our land is currently excluded from Canada's national balance sheet, including all publicly owned forests and parkland. A key role of the Land Account then is the establishment of values for these areas. (Section 3.5.7 provides a more complete discussion of the issues surrounding land valuation.)

3.5.2 Components of the Land Account

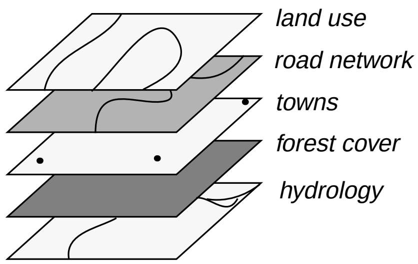
There are five main components, or layers, in the Land Account. These are broadly defined below.

1. The physical foundation - An accurate spatial frame used for the estimation of all other components of the account.

2. Land cover - The physical nature of the land's surface (e.g. urban built-up areas, mature forest).

Text Box 3.9
Capabilities of GIS Technology

A GIS stores data electronically in various layers, each one representing a separate theme or selection of themes (like electronic maps). These digital images can be easily edited, projected or overlaid one on top of the other. The analytical power of a GIS comes from its ability to dissect and relate disparate layers of geographic information. When overlaid, these layers can be analysed cross-sectorally to determine how the various themes are spatially correlated. This tool is extremely useful for performing area calculations as well as for sorting-out complex spatial relationships.



3. Land use - A description of how land is used for commerce (e.g., agriculture), non-commercial activities (e.g., recreation) and ecological purposes (e.g., wildlife breeding).

4. Land potential - The biophysical properties of land (e.g., climate, geology, topography, soil characteristics).

5. Land value - Market and non-market direct-use values (e.g., agriculture and recreation), indirect-use values (e.g., flood control), and non-use values (e.g., wildlife habitat).

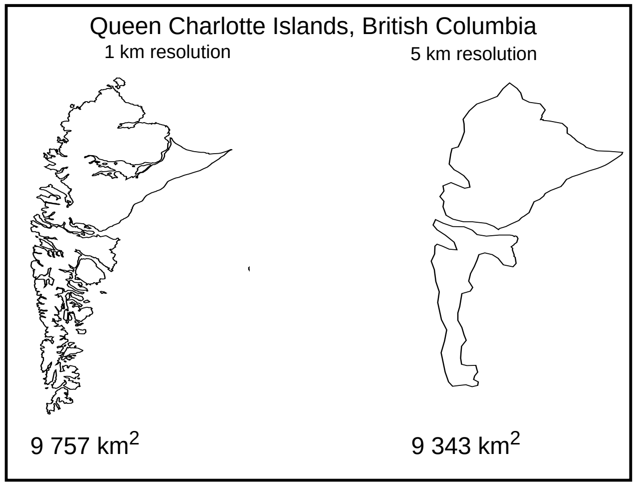
The second through fifth layers of the account rely on the methods and standards employed in the first layer.

3.5.3 Layer 1: The physical foundation

The first layer of the Land Account accurately delineates Canada's land and water areas. Building this layer involved the assembly, estimation and validation of physical data from various sources at an ecoregion[1] level (1 : 1 million scale). The use of Geographical Information System (GIS) technology[2] made this daunting task manageable. Digital images can today be rapidly manipulated to yield high-quality area estimates suitable for statistical analysis; twenty years ago this would have been an onerous task using with paper maps and manual tools.

1. Ecoregions are large natural units delineated by distinctive sets of non-living (abiotic) and living (biotic) resources that are ecologically related.
2. Text Box 3.9 demonstrates how a basic GIS functions.

Figure 3.6
The Effect of Resolution on Area Estimates



Accurate area estimates

Land and water areas for Canada are calculated using a modified version of the digital map *Terrestrial Ecozones and Ecoregions for Canada 1995* (Ecological Stratification Working Group, 1995) This map, which was compiled at scales ranging from 1 : 1 million to 1 : 2 million, has been merged with a 1 : 1 million shoreline map from the *Digital Chart of the World* (DCW) (Environmental Systems Research Institute, 1993). The DCW provides a high resolution digital image of Canada's shorelines. High resolution is important in this context, because the accuracy of area estimates is directly related to the resolution of the map used to define boundaries.[3] The accurate delineation of coasts, lakes and rivers is particularly important for Canada, which has more shoreline than any other country in the world. Figure 3.6 illustrates the importance of resolution in calculating area. Area estimates for the Queen Charlotte Islands are presented using two different map resolutions; the difference between the two land area estimates is more than four percent.

Ecological framework

The use of an ecological framework is an important element of the Land Account. Text Box 3.10 describes the ecological land classification hierarchy that is employed by the Federal/Provincial Ecological Stratification Working Group. This hierarchy has been adopted for the Land Account. Three of the seven levels in the *Canadian Ecological Land Classification* are described in Text Box 3.10. The 15 ecozones in Canada can be broken down into 217 different ecoregions, which can be further sub-divided into 5 395 ecodistricts.

3. Resolution defines the smallest object that is discernable on a map. At a resolution of 1 km, objects smaller than 1 km^2 in size are not discernable. For example, a school yard would not be discernable at 1 km resolution, while a large military base would be. Given the technology available for the production of the Land Account a map scale of 1 : 1 million represents a resolution of roughly 1 km.

Text Box 3.10

Ecological Land Classification Hierarchy

Generalized

Ecozone The highest level of the hierarchy. Canada is divided into 15 ecozones. See Map 3.4 (page 60).

Ecoregion Distinguished by unique ecological areas influenced by climate regimes. There are 217 ecoregions in Canada.

Ecodistrict Part of an ecoregion, with distinctive assemblages of relief, vegetation, fauna, water, soils, landforms and geology. There are 5 395 ecodistricts in Canada.

Detailed

Source:
Ecological Stratification Working Group, 1995.

Ecoregions serve as a useful geographic frame for the analysis of land information. These units have the advantage of boundaries that are relatively fixed over time, unlike administrative or politically bounded areas that can change significantly from one year to the next in response to a population change or an administrative decision. Another advantage of ecoregions as spatial units is that they are defined by distinct non-living (abiotic) and living (biotic) resources that are ecologically related. Soil type, surface mineral deposits and landforms are all examples of land-related resources that are integral to the definition of an ecoregion. Since ecoregions represent common physiographic and biophysical characteristics and are fixed over time, they make excellent spatial units for the Land Account.

Map 3.4 (page 60)[1] presents the results of merging the ecozone/ecoregion coverage (or digital map) with the detailed DCW shoreline. For display purposes the ecoregion lines have been suppressed to show only the broader ecozone boundaries.

Geo-statistical units

To facilitate the integration of demographic, social and economic data into the Land Account, a geo-statistical hierarchy consistent with that used for Statistics Canada's surveys is employed in the account. Statistics Canada's *1991 Enumeration Area Digital Boundary File* defines the boundaries for these geo-statistical units (Statistics Canada, 1991b). The units that have been adopted for use in the Land Account include:

- provinces/territories (12);
- census divisions (295);
- census subdivisions (6 006);
- consolidated census subdivisions (2 630);
- enumeration areas (45 995);

Data from many of Statistics Canada's surveys are available using these standard units.

An example of the geo-statistical hierarchy used in the Land Account is presented in Map 3.1 for one small area–Census Division 3546 in Ontario.

To summarize, the physical foundation (first layer) of the Land Account is defined by the union of detailed coverages of ecoregions, shorelines and enumeration areas. This layer has 217 ecoregions, 10 provinces and two territories comprising 5 659 separate units when split by provincial/territorial boundaries. Additional layers in the account must all conform to the spatial standards established by the union of these three spatial frameworks.

3.5.4 Layer 2: Land cover - vegetation and other surface features

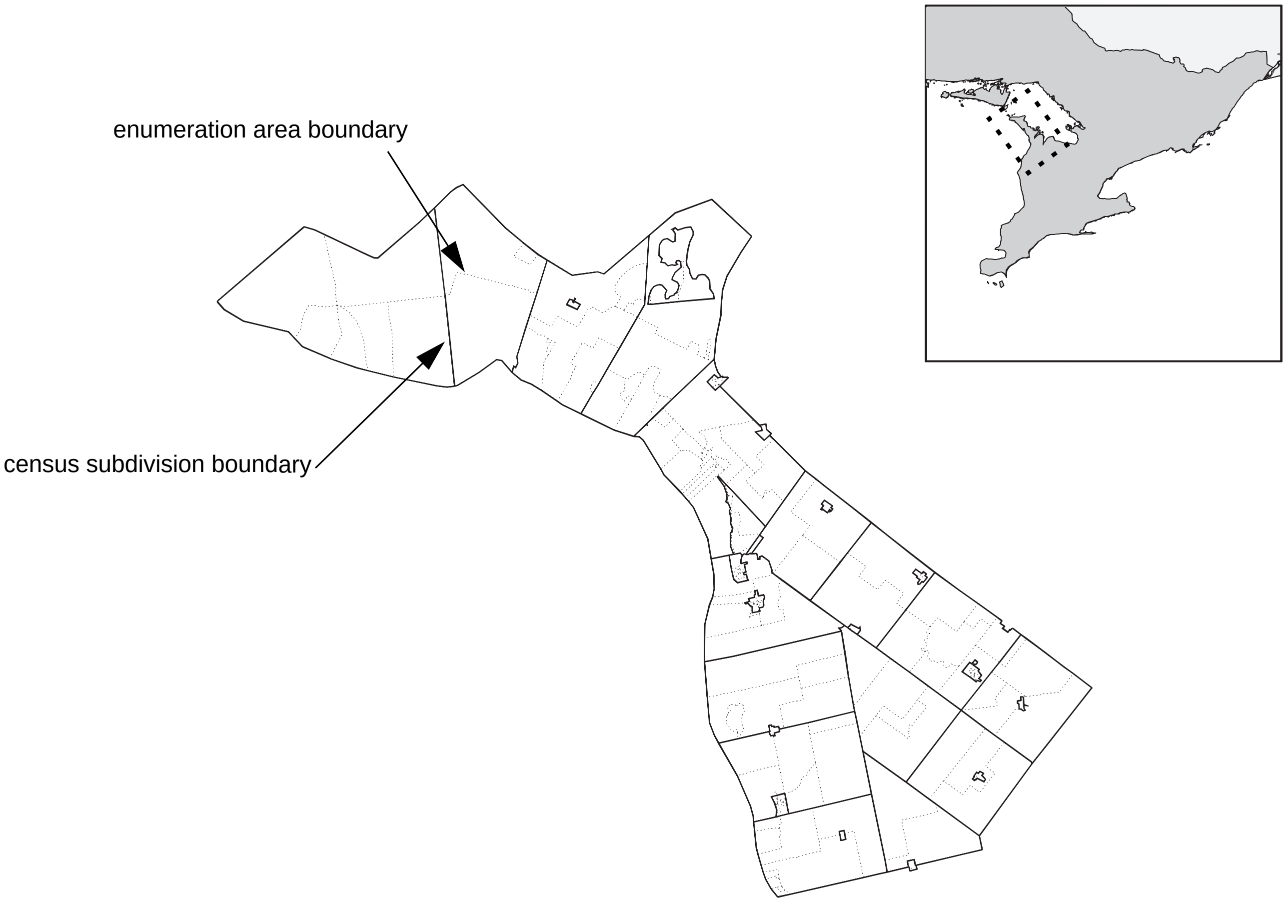
Land cover, which forms the second layer in the Land Account, is a characterization of the surface properties of the land. Land-cover information is a basic requirement for the determination of land use and, ultimately, land value. Initial land-cover information for the Land Account has been taken from satellite imagery. Natural Resources Canada and Forestry Canada have compiled a composite land-cover picture for all of Canada (Natural Resources Canada and Forestry Canada, 1994).[2] This large satellite picture was obtained from Advanced Very High Resolution Radiometry and has a maximum ground resolution of one kilometre. Land-cover data are available for ten separate land-cover classes and two water-cover classes.

Map 3.5 (page 61) displays the composite land-cover picture for all of Canada. In this map, land and water classes have been collapsed to form six classes rather than twelve. The full twelve classes are listed in Text Box 3.11 (page 57). The digital land cover snapshot has been manipulated by the GIS to conform to the spatial standards of the detailed ecoregion/shoreline/enumeration area coverage in layer 1. An example of the results of the union between the first and second layers in the account is presented in Map 3.2 (page 55). Similar land-cover statistics can be generated for any area in Canada. Information of this sort in a time-series format is useful for environmental monitoring and resource management.

1. This large map, along with several others, is presented at the end of this section to avoid disrupting the main text.

2. The image was compiled from 45 separate satellite photos taken between 1989 and 1992. A composite picture of the entire country is difficult to obtain because of cloud cover interference and seasonal variations in surface reflectance due to snow and other physical factors.

Map 3.1
Ontario Census Division 3546 and Constituent Geo-statistical Hierarchy



Source:
Statistics Canada, National Accounts and Environment Division.

3.5.5 Layer 3: Land use

The third layer in the Land Account is land-use. This layer is more complex than the first two because the activities it describes often overlap. Land-use activities can number in the thousands on a given parcel of land if both natural and human activities are considered. Examples of natural processes that use land include water absorption and evaporation, vegetation growth and decay, and even seasonal heat loss and gain. Human land-using activities range from low intensity uses like recreation, to more intensive activities such as agriculture and forestry.

Detailed land-use trends are important indicators of changing biodiversity and environmental sustainability. Today's societies' impact on the environment can be measured in part through the changes it makes to land use patterns.

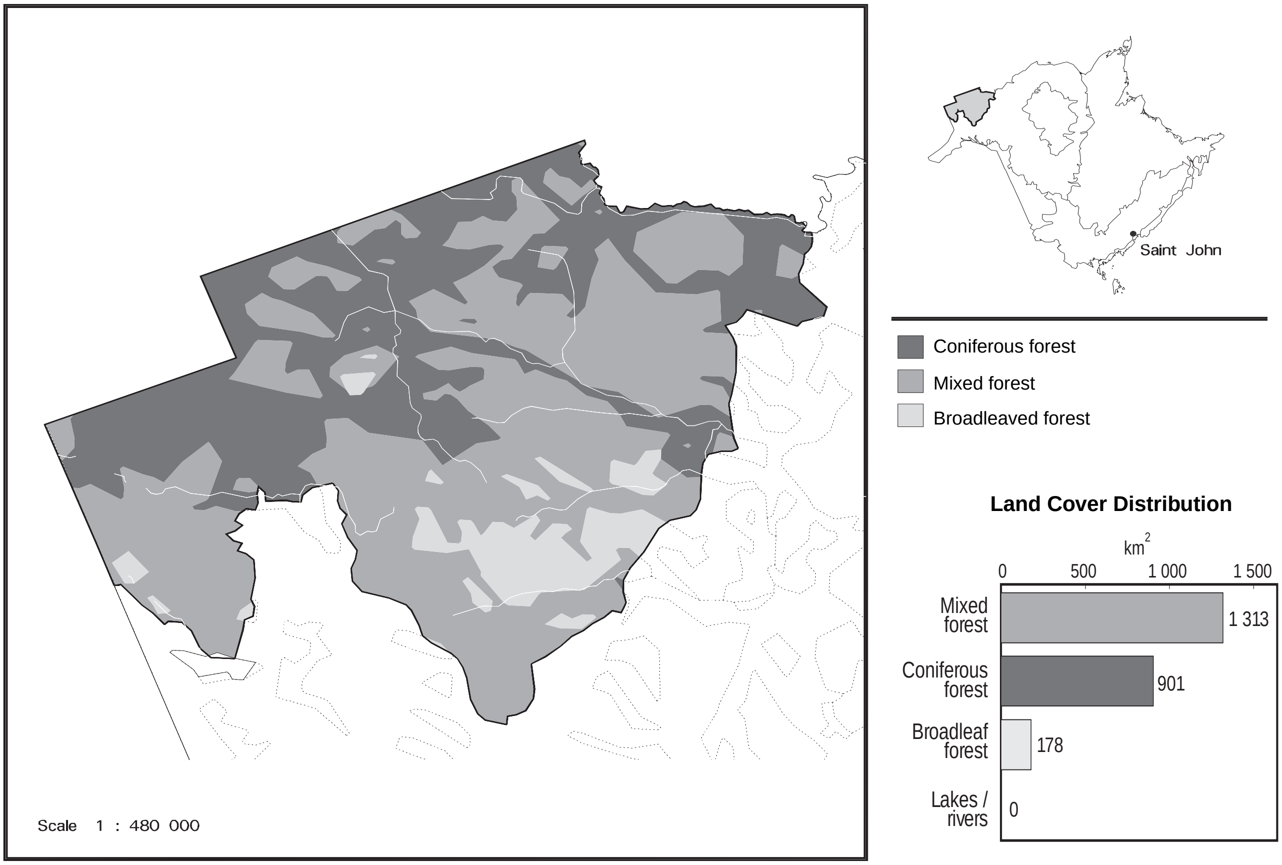
As mentioned earlier (page 51), the Land Account currently employs a macro land-use classification that is Canada-wide. Text Box 3.12 (page 57) summarizes the land-use framework on which this classification is based, while Text Box 3.13 (page 57) shows the land-use classes themselves. The Land Account includes estimates of land use by ecozone for all of Canada (217 ecoregions) for the seven land-use classes defined in Text Box 3.13. Where possible, this information is provided on a time-series basis so that changes can be highlighted and assessed over time.

As well as using the broad land-use classes listed in Text Box 3.13, the Land Account is also able to draw upon Statistics Canada's Environmental Information System (EIS) to provide more detailed land-use information. This is possible because of the GIS and its ability to combine disparate spatially-referenced information. The EIS is a GIS database that contains a wide variety of Statistics Canada's social and economic time-series data. Many of the series are useful in the development of land-use indicators; for example, population distribution and density, dwellings, agricultural land value, major crop type, quantities of fertilizer applied to cropland, and industrial information.

Agricultural land use

Information on agricultural land use for the Land Account comes from the *Census of Agriculture*. The extent of farm-

Map 3.2
Land Cover for the New Brunswick Portion of the Appalachians Ecoregion, 1992



Source:
Statistics Canada, National Accounts and Environment Division.

land in Canada is taken from the census' "agricultural ecumene" for 1991. This ecumene (or land area) is based on the distribution of farms within enumeration areas. Individual agricultural land-use activities are derived from the *Census of Agriculture* at the enumeration area level and are available for 1971, 1976, 1981, 1986 and 1991. The land-use information is available at two basic levels of aggregation. The most detailed level describes individual crops, pasture type and even barnyard areas, while the more aggregate information separates land into two broad classes, referred to as improved and unimproved farmland. A time-series of agricultural land use for Canada as a whole is presented in Table 3.11 to illustrate the aggregate agricultural information that is available in the Land Account.

Annex 3.1 lists all of the land-use variables available from the *Census of Agriculture* as well as the years for which they are available. For any given ecoregion and census year between 1971 and 1991, information on the mix of crops, the types of livestock and hundreds of other agricultural land uses is available. It should be noted that this information is limited to commercial land uses; other uses such as wildlife habitat are not yet addressed.

Forestland use

Forest information in the Land Account comes from two sources. The extent of the forests is obtained from the *Canada Vegetation Cover-Digital Satellite Image* (Natural Resources Canada and Forestry Canada, 1994). Land-use information for forests is taken from CanFI91 (Lowe, Power and Gray, 1994), which stratifies Canada's forestland according to 11 characteristics.[1] Map 3.6 (page 62) illustrates some of the information from CanFI91 that has been incorporated into the Land Account.

Urban and rural land use

The urban and rural components of the land-use layer for the Land Account are presented for Southern Ontario in Map 3.3 (page 58). This information is based on urban area figures from Statistics Canada's *1991 Digital Enumeration Area Polygon File* (Statistics Canada, 1991b). Of the 45 995 enumeration areas in 1991, 29 802 were classified

1. Data source; ownership status; land class; site quality; stocking; cause of disturbance; age; maturity; forest type; predominant genus year of information.

as urban, while 16 193 were rural. An urban EA is one where the population had reached at least 1 000 with a density of at least 400 persons/km^2 at the time of the last population census.

Urban and rural land-use estimates for the Land Account are available for census years 1971, 1981, 1991 and 1996.[1] In 1991, urban EA polygons with non-zero populations were used as a baseline for calculating urban areas in other census years. These estimates are based on the spatial distribution of EA centroids in each census year. Urban EA centroids are given an average urban area from the *1991 Digital Enumeration Area Polygon File*. The EA centroids are then given circular buffers to represent urban land use. The results for 1971 and 1996 are presented in Map 3.3.

3.5.6 Layer 4: Land potential

Land potential, the fourth layer in the Land Account, provides a measure of land capability. It is derived from biophysical parameters such as climate, soil, geology, slope and drainage. Historical land-capability data from the *Canada Land Inventory* (CLI) (Environment Canada, 1981) are the basis for the land potential data in the account.

The dominant land use on a parcel of land is often not a reflection of the land's physical potential. In some cases location is a stronger determinant of use than is physical potential, and trade-offs are commonly made regarding the final use of land. Every parcel of land in Canada has many different use potentials and these commonly overlap. Information on land potential is thus useful in planning for the most efficient use of our land resources.

3.5.7 Layer 5: Land value

An important role of the Land Account is to provide extended estimates of the value of Canada's land for inclusion on the CNBSA. Currently, the land included on the national balance sheet is treated as a tangible, non-produced asset and recorded as "commercial land." Commercial land is restricted to land under residential and non-residential buildings, plus agricultural land. Residential land values are derived from Canada Mortgage and Housing Corporation building-permit data; the value of land under non-residential buildings is derived from capital stock information. Values for agricultural land are taken from farm real estate values reported to the *Census of Agriculture.* The agricultural land estimates are further split between land and buildings.

Notable in the current treatment of land in the CNBSA is the exclusion of much of Canada's land area. This includes, for example, all publicly owned forests and parkland. A key role of the Land Account is to establish values for these areas. The data on land use and land potential from layers 3 and 4 of the account will be used as the basis for these extended value estimates. Estimates will be made for the value of "direct-uses" that are not currently on the balance sheet, such as recreational and forest use, and, if suitable methodologies can be developed, for "indirect-use" and "non-use" values as well.[2]

1. Preliminary estimates only are available for 1996.

Table 3.11
Agricultural Land Use, 1901-1991

Year	Improved farmland				Unimproved farmland	Total farmland
	Cropland	Improved pasture	Summer-fallow	Other land[1]		
	million hectares					
1901	8.1	--	--	4.1	13.5	25.7
1911	14.4	--	1.0	4.3	24.4	44.1
1921	20.2	3.1	4.8	0.5	28.4	57.0
1931	23.6	3.2	6.8	1.1	31.3	66.0
1941	22.8	3.4	9.5	1.4	33.1	70.2
1951	25.2	4.0	8.9	1.1	31.2	70.4
1961	25.3	4.1	11.4	1.0	28.0	69.8
1971	27.8	4.1	10.8	1.0	25.0	68.7
1976	28.3	4.1	10.9	0.9	24.2	68.4
1981	30.9	4.1	9.7	1.4	19.8	65.9
1986	33.2	3.6	8.5	0.7	21.8	67.8
1991	33.5	4.1	7.9	..	..	67.8

Note:
1. Other land refers to barnyards, laneways and other unclassified lands.
Source:
Statistics Canada, *Census of Agriculture.*

The extent to which these extended land valuations will ultimately be reflected in the CNBSA remains unresolved. Where suitable methods can be developed to value direct uses of land that are not currently valued–forests and parks for example–these estimates will eventually be included on the balance sheet. Decisions on the inclusion of other, less clearly defined, values–to the extent that these can be estimated–will be made in the future.

3.5.8 Data gaps

Very little information exists for industrial land use or for sanitary landfill sites and dumps. Estimation techniques will have to developed if these and other high impact land uses are to be tracked over time.

Certain direct, and all non-direct, land uses also pose a sizable data gap. What is the extent of recreational land in Canada? What lands are used by which species of wildlife? These questions must be addressed if we are to accurately describe Canada's land-use patterns.

From a valuation perspective, large data gaps exist for land areas such as nature preserves and wilderness areas. These have considerable societal value, but applying monetary values to them is difficult since they are not priced in the marketplace. Developing suitable non-market valuation methodologies for these resources remains a challenge.

2. Direct-use values are those associated with human interaction with the land (agriculture and recreation for example). Indirect-use values are the values of the services (or functions) that humans derive from the land without actually using the land directly (flood and climate control for example). Non-use values include, among others, value derived from the knowledge of the continued existence of a species beyond its value for human use.

Text Box 3.11

Land Cover Classification

Coniferous forest: Continuous forest, 75 - 100 percent composed of coniferous trees.

Broadleaved forest: ContInuous forest, 75 - 100 percent composed of broadleaved trees.

Mixed forest: Continuous forest, 26 - 75 percent composed of broadleaved or coniferous trees.

Transitional forest: A mixture of land cover classes where tree cover is discernable but covers less than 50 percent of the area. Tree density varies from open woodland to scattered groves of trees.

Tundra: Treeless arctic and alpine vegetation with nearly continuous plant cover.

Sparsely vegetated / barren land: Plants cover less than 25 percent of the surface.

Cropland: Land cultivated with crops.

Rangeland and pasture: Land supporting native vegetation, also includes improved and unimproved pasture.

Perennial snow and ice: Snow fields and glaciers.

Urban built-up area: Defined as all land within urban enumeration areas at the time of the *1991 Census of Population*.[1]

Open water

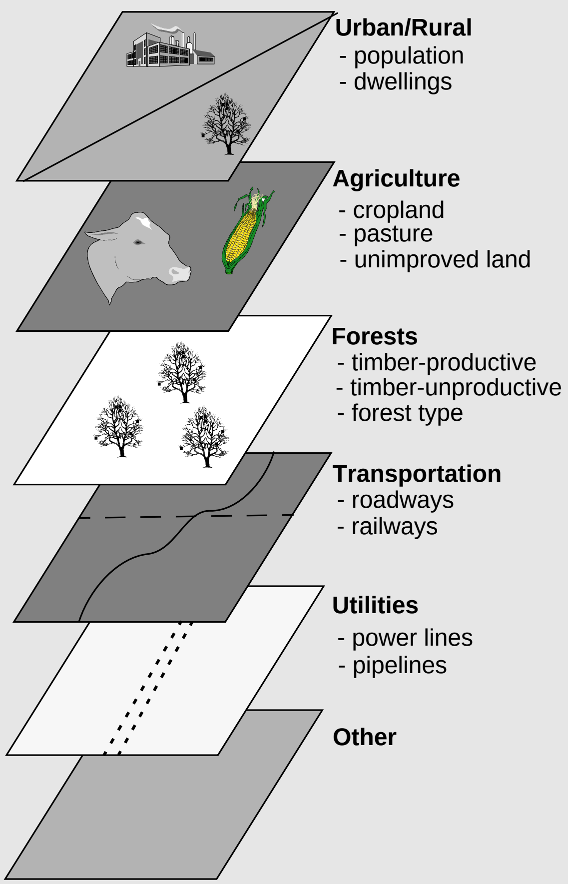
Sea ice

Note:
1. An urban enumeration area is one that had attained a population of at least 1000 and a population density of at least 400 people per square kilometre at the time of the previous census.

Sources:
Natural Resources Canada and Forestry Canada (1994); Statistics Canada (1971, 1981, 1991a and 1991b).

Text Box 3.12

Land-use Framework



Text Box 3.13

Land-use Classification

Urban land: All land included in urban enumeration areas as defined by the *1991 Census of Population*.[1]

Rural land: All land included in rural enumeration areas as defined by the *1991 Census of Population*.[2]

Agricultural land: All land included in agricultural enumeration areas in the *1991 Census of Agriculture.* Enumeration areas are proportionally allocated between ecoregions where necessary. Digital satellite vegetation cover information is used to assign agricultural land use within large enumeration areas and to cross check statistics within ecoregions.

Forestland: Timber-productive and timber-unproductive forestland as defined in CanFI91 (Lowe, Power and Gray, 1994).

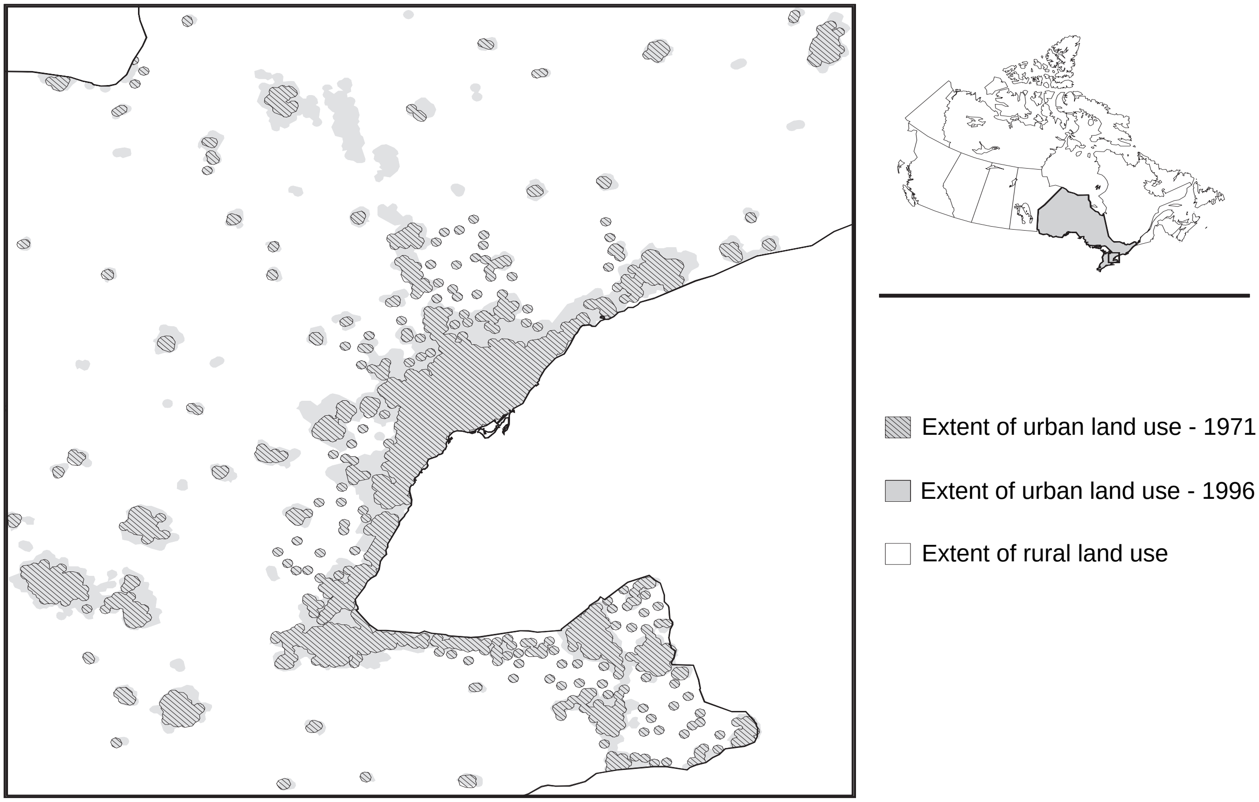
Transportation land: Land used for primary and secondary paved roads.

Utilities land: Land used for power transmission lines, telephone lines and pipelines.

Other: Land not classified elsewhere. For example, land used for tourism, recreation, wildlife habitat and other types of infrastructure is classified as “other.”

Notes:
1. An urban enumeration area is one that had attained a population of at least 1000 and a population density of at least 400 people per square kilometre at the time of the previous census. Urban area estimates are from Statistics Canada (1991b).
2. Rural areas include all areas that do not meet the urban definition. Rural area estimates are from Statistics Canada (1991b).

Map 3.3
Urban and Rural Land Use in Southern Ontario, 1971 and 1996



Source:
Statistics Canada, National Accounts and Environment Division.

3.5.9 Future directions for the Land Account

The Land Account in its current form represents a significant advance in the land statistics available to Canadians at the national level. This is particularly true when one considers that collecting national land information has not been a recent priority for the federal government (as land resources are mainly within provincial/municipal jurisdiction). Notwithstanding the strides that have already been made, there is still much scope for improving the current estimates and expanding the account in new directions. To this end, research in the immediate future will focus in the areas outlined below.

- Given that much of Canada's land resource falls under the jurisdiction of provincial governments, Statistics Canada will seek provincial input in the further development of national land statistics. For the most part this will involve the reorganization of existing information. In several years' time the account will be able to take advantage of highly detailed digital cadastral information[1] that will become available for most provinces in Canada.
- More complete land-use classifications will be required once detailed provincial data are integrated into the account. Future editions of the Land Account will also require classifications that are more consistent with international standards.[2] The use of the CLUMP land classifications (see page 51), which go a long way toward satisfying both of these needs, is under investigation.
- The forest land-use information included in the account to date represents only a first approximation of forestland use. The initial focus on commercial uses of the forest will be expanded through the development of information on non-market uses such as recreation and wildlife habitat.
- The CLI data used to estimate land potential in the account represent the best data currently available. They are, however, somewhat out of date and not as geographically detailed as they might be. Future versions

1. Cadastral information comes from provincial property registers, and includes lot size, location, land value and assessed taxes.
2. Annex 3.2 presents one such classification: the *Standard International Classification of Land Use* (United Nations Statistical Commission and Economic Commission for Europe, 1985).

of the account will seek to use more detailed geology, soil, climate and drainage information to represent land potential.

- In view of the need for measures of the sustainability of economic activity, there is reason to re-examine the land values currently included in the CNBSA. This is particularly true for agricultural land. Current agricultural land values, which represent the market value assigned to agricultural land by farmers, are problematic in two ways. First, they may not reflect all the environmental costs and benefits of agricultural activity. Second, they often contain large speculative elements that do not reflect the value of the land for agriculture, but its value in some alternative use (often for urban development). Thus, these values may be unsuitable for use in assessing the long-term economic and environmental sustainability of agricultural activity. Developing alternative, more relevant values of agricultural land is a complicated issue and Statistics Canada has not yet developed a suitable methodology. To date, preliminary land-value estimates have been calculated for agricultural land in New Brunswick (McAuley, 1996). This pilot project attempted to calculate the value of agricultural land by estimating its economic rent. While the results of the project revealed serious methodological and data shortcomings, the lessons learned will be used to further refine the method for eventual application to the rest of the country.

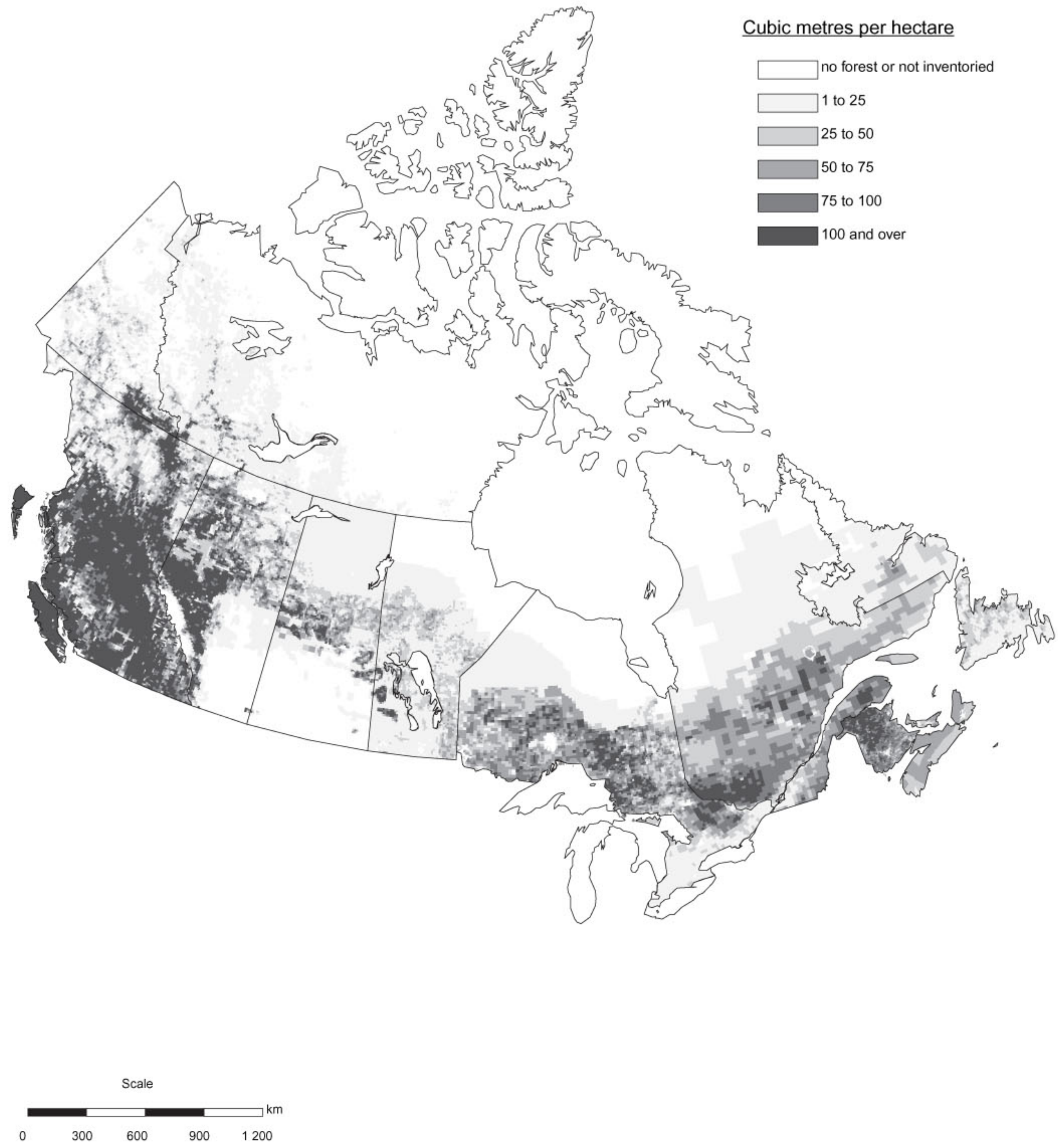
Map 3.4
Terrestrial Ecozones of Canada

Source:
Ecological Stratification Working Group, 1995.

Map 3.5
Land Cover, 1992

Source:
Natural Resources Canada and Forestry Canada, 1994.

Map 3.6
Wood Volume, All Species, 1991



Note:
Volume per hectare is calculated relative to total cell land area (including rivers and lakes).
Source:
Lowe, Power and Gray, 1994.

Annex 3.1
Land-use variables from the *Census of Agriculture*

			Year				
Variable	Unit of measure	Description	71	76	81	86	91
AOWNED	hectares	Area owned	*	*	*	*	*
ARNTED	hectares	Area leased or rented from individuals				*	*
ARNTEDT	hectares	Total area leased or rented, including governments	*	*	*	*	*
CRPLND	hectares	Total area of cropland	*	*	*	*	*
FLOOD	hectares	Area irrigated by flood				*	
HANDMO	hectares	Area irrigated by hand moved water				*	
IMPAST	hectares	Improved pasture	*	*	*	*	*
OTHIMP	hectares	Other improved land		*	*	*	
OTHIRG	hectares	Other irrigated area				*	
OUNIMP	hectares	Other unimproved land and unimproved pasture	*	*	*	*	
PIVOT	hectares	Area irrigated by pivot				*	
SUMMRF	hectares	Summerfallow	*	*	*	*	*
TFAREA	hectares	Total area of land operated	*	*	*	*	*
TILEDRN	hectares	Total area under drainage				*	
TOTFER	hectares	Total area fertilized	*		*	*	*
TOTIMP	hectares	Total improved land	*	*	*	*	
TOTIRG	hectares	Total area irrigated	*		*	*	*
TOTUNIM	hectares	Total unimproved land	*	*	*	*	
UNIMPAST	hectares	Unimproved pasture	*			*	*
VOLGUN	hectares	Area irrigated by volume gun				*	
WDLAND	hectares	Woodland	*	*	*	*	
WHEEL	hectares	Area irrigated by wheelroll				*	
FEEDPD	dollars	Feed purchased	*		*	*	*
APCTTA	hectares	Apricot orchards	*		*	*	*
APLETA	hectares	Apple orchards	*		*	*	*
OTTFTA	hectares	Other tree fruit orchards				*	*
PEARTA	hectares	Pear orchards	*		*	*	*
PECHTA	hectares	Peach orchards	*		*	*	*
PLUMTA	hectares	Plum and prune orchards	*		*	*	*
SRCHTA	hectares	Sour cherry orchards	*		*	*	*
TOTTFT	hectares	Total tree fruit orchards	*	*	*	*	*
BARLEY	hectares	Barley for grain	*	*	*	*	*
BLUEBC	hectares	Cultivated blueberries				*	*
BUCWHT	hectares	Buckwheat	*	*	*	*	*
CANARY	hectares	Canary seed			*	*	*

Variable	Unit of measure	Description	Year				
			71	76	81	86	91
CANOLA	hectares	Canola	*	*	*	*	*
CARAWAY	hectares	Caraway seed				*	*
CORNEN	hectares	Corn for silage	*	*	*	*	*
CORNGR	hectares	Corn for grain	*	*	*	*	*
CRANBC	hectares	Cultivated cranberries				*	*
DFPEAS	hectares	Dry field peas	*	*	*	*	*
FABABN	hectares	Fababeans			*	*	*
FBEANS	hectares	Total dry beans	*	*	*	*	*
FCROPS	hectares	Other fodder crops				*	*
FCROPST	hectares	Total other fodder crops (including barley for feed)	*	*	*	*	
FDBARL	hectares	Barley for feed				*	
FDOATS	hectares	Oats for feed	*	*	*	*	
FLAXSD	hectares	Flaxseed	*	*	*	*	*
FORAGESD	hectares	Forage seed			*	*	*
GRAPESC	hectares	Cultivated grapes	*		*	*	*
LENTIL	hectares	Lentils			*	*	*
MILLET	hectares	Millet for grain			*	*	*
MUSTSD	hectares	Mustard seed	*	*	*	*	*
MXDGRN	hectares	Mixed grains	*	*	*	*	*
NURSERY	hectares	Nursery products	*	*	*	*	*
OATSGR	hectares	Oats for grain	*	*	*	*	
ODFBNS	hectares	Other dry beans				*	*
OFIELD	hectares	Other field crops residuals			*	*	*
OTHBERC	hectares	Other cultivated berries	*		*	*	*
POTATS	hectares	Potatoes	*	*	*	*	*
RASPBC	hectares	Cultivated raspberries	*			*	*
RTCROP	hectares	Root crops for feed			*	*	
SAFLWR	hectares	Safflower			*	*	*
SODGRN	hectares	Sod grown for sale			*	*	*
SOYBNS	hectares	Soybeans	*	*	*	*	*
STWBRYC	hectares	Cultivated strawberries	*		*	*	*
SUGARB	hectares	Sugar beets	*	*	*	*	*
SUNFLS	hectares	Sunflowers	*	*	*	*	*
SWCHTA	hectares	Sweet cherry orchards	*		*	*	*
TAMHAY	hectares	Tame hay	*	*	*	*	
TOBACO	hectares	Tobacco	*	*	*	*	*
TOFIELD	hectares	Total other field crops	*	*	*	*	*

Variable	Unit of measure	Description	Year				
			71	76	81	86	91
TOTHAY	hectares	Total hay	*	*	*	*	*
TOTOAT	hectares	Total oats	*	*	*	*	*
TOTOIL	hectares	Total oilseeds				*	*
TOTRYE	hectares	Total rye	*	*	*	*	*
TOTVEG	hectares	Total vegetables	*	*	*	*	*
TOTWHT	hectares	Total wheat	*	*	*	*	*
TRITCL	hectares	Triticale			*	*	*
TSMFRTC	hectares	Total small fruits	*	*	*	*	*
WHITBN	hectares	White beans				*	*
OTHLND	hectares	All other land, including woodland and improved and unimproved land, nec					*
SPINST	hectares	Area sprayed for insects	*		*	*	*
SPWEED	hectares	Area sprayed for weeds	*		*	*	*
FLOWER	square meters	Greenhouse flowers				*	*
GRMUSH	square meters	Total mushroom and greenhouse products	*	*	*	*	*
MUSHRM	square meters	Mushrooms	*		*	*	*
OTHERGRN	square meters	Other greenhouse products				*	*
TOTGRN	square meters	Total greenhouse products	*		*	*	*
VEGET	square meters	Greenhouse vegetables				*	*
BFCOWS	units	Beef cows					*
BFHEFS	units	Beef heifers					*
BFSLGH	units	Slaughter heifers					*
BULLS	units	Bulls					*
CALFU1	units	Calves under 1 year					*
HORSES	units	Horses	*		*	*	*
MLKCOW	units	Milk cows					*
MLKHEF	units	Milk heifers					*
STEERS	units	Steers					*
TCATTL	units	Total cattle	*	*	*	*	*
TOPIGS	units	Pigs	*	*	*	*	*
TSHEEP	units	Total sheep	*	*	*	*	*
TOTPLT	units	Total poultry	*	*	*	*	*

Annex 3.2
Standard International Classification of Land Use

1 Agricultural land
- 1.1 Arable land
- 1.2 Land under permanent crops
- 1.3 Land under permanent meadows and pastures
- 1.4 All other agricultural land, nec

2 Forest and other wooded land
- 2.1 Land under coniferous forest
  - 2.1.1 With wood production the recognized major function
  - 2.1.2 With protection, conservation and biological use the recognized major function
  - 2.1.3 With recreation the recognized major function
- 2.2 Land under non-coniferous forest
  - 2.2.1 With wood production the recognized major function
  - 2.2.2 With protection, conservation and biological use the recognized major function
  - 2.2.3 With recreation the recognized major function
- 2.3 Other wooded land
  - 2.3.1 With wood production the recognized major function
  - 2.3.2 With protection, conservation and biological use the recognized major function
  - 2.3.3 With recreation the recognized major function

3 Built-up and related land (excluding farm buildings)
- 3.1 Residential land
  - 3.1.1 With mainly one or two-storey buildings
  - 3.1.2 With mainly three (or more) storey buildings
- 3.2 Industrial land (excluding land classified under below)
- 3.3 Land used for quarries, pits, mines and related facilities
- 3.4 Commercial land
- 3.5 Land used for public services and facilities, excluding transport and communication facilities
- 3.6 Land of mixed use
- 3.7 Land used for infrastructure facilities
  - 3.7.1 Land under motorways
  - 3.7.2 Land under other roads
  - 3.7.3 Land under railways
  - 3.7.4 Land under airports and related facilities
  - 3.7.5 Land under harbour and related (storage) facilities
  - 3.7.6 Land under high-voltage transmission lines and under (surface) pipelines for the transport of fuels and other products
  - 3.7.7 Other land for infrastructure
- 3.8 Recreational land
  - 3.8.1 Recreational land occupied by camping sites, secondary residences or vacation homes
  - 3.8.2 Other recreational lands nec
- 3.9 Land used for the disposal of wastes
  - 3.9.1 Land used for the disposal of municipal waste
  - 3.9.2 Land used for the disposal of industrial and commercial wastes, including junk yards
- 3.10 Related open land
- 3.11 Other built-up land nec

4 Wet open land
- 4.1 Mires
  - 4.1.1 Ombrogenous mires
  - 4.1.2 Soligenous mires
- 4.2 Wet tundra
- 4.3 Other wet open land nec

5 Dry open land with special vegetation cover
- 5.1 Heathland
- 5.2 Dry tundra
- 5.3 Mountainous grassland
- 5.4 Other nec

6 Open land without, or with insignificant, vegetation cover
- 6.1 Bare rocks, glaciers, perpetual snow
  - 6.1.1 Bare rocks
  - 6.1.2 Glaciers and perpetual snow
- 6.2 Sand beaches, dunes, other sandy land
- 6.3 Other nec

7 Waters
- 7.1 Inland waters
  - 7.1.1 Natural watercourses
  - 7.1.2 Artificial watercourses
  - 7.1.3 Inland sea (freshwater or saline), lakes, ponds, coastal land-locked water bodies
  - 7.1.4 Artificial water impoundments
  - 7.1.5 Other inland waters nec
- 7.2 Tidal waters
  - 7.2.1 Coastal lagoons
  - 7.2.2 Estuaries
  - 7.2.3 Other tidal waters nec

Source:
United Nations Statistical Commission and Economic Commission for Europe, 1985.

4 Material and Energy Flow Accounts

Introduction

The Material and Energy Flow Accounts (MEFA) represent the second major component of the System of Environmental and Resource Accounts described in this volume. The MEFA record in substantial detail the annual flows of materials and energy–in the form of resources and wastes–between the Canadian economy and the environment. These flows are related to the activities of industries, households and governments, and they are recorded as such in the accounts. Data for over 160 industries, plus a wide array of household and government activities are presented. The MEFA share their classifications of industries, households and governments with Statistics Canada's Input-Output Accounts (Statistics Canada, 1987).[1] This allows the environmental data in the MEFA to be linked directly and easily with the economic data found in the Input-Output Accounts, adding value to both data sets.

Along with their detailed portrait of economic activity, the MEFA present an equally detailed view of the associated resource and waste flows. In principle, the accounts record all the resources and wastes that cross the environment/economy boundary. In practice, they are limited in what they can offer by the range of data available. Statistics Canada and other public and private organisations are working to expand this range, so that the detail with which the MEFA cover resource and waste flows will expand with time.

The MEFA represent a unique source of environmental information, never before available in Canada. Although some of the basic data that they present are available elsewhere, these data are typically dispersed among many organisations and are often difficult to access. The MEFA represent the first effort to bring these resource and waste data together as a single, consistently organised and comprehensive set. The accounts can thus be thought of as a kind of "one-stop-shopping" for resource and waste flow data. More importantly, they represent the first time that detailed data on resource and waste flows have been directly linked with the rich body of economic statistics available from Statistics Canada. It is this linkage of economic and environmental data, within the well-established and widely-used framework of the CSNA, that represents the true strength of the MEFA (and indeed of the other components of the CSERA). The analytical power that this linkage offers contributes substantially to our ability to study the Canadian economy and the demands it places on the environment. Such understanding has an important role to play in the informed management of the economy toward the simultaneous realisation of our economic and environmental goals.

1. For those readers not familiar with these accounts, they are described in detail in Annex 4.1.

Scope of the accounts

The MEFA are compiled on an annual basis, intentionally matching the frequency of the Input-Output Accounts. This accounting period is generally compatible with environmental data as well, many of which are compiled annually. Moreover, one year is an appropriate time frame for analysing many material and energy flows. Resource consumption, for example, is not highly time-sensitive, as resources tend to be used over long periods of time. Likewise, many of the environmental effects associated with wastes manifest themselves not over months, but over years and decades. Some waste-related effects are highly time sensitive however–eutrophication of waterways and urban smog for example. For these effects there is a very short time lag between release of the responsible wastes and the appearance of the effect. Although a shorter reporting period might be more suitable for such wastes, given current environmental data, an annual frequency is the best achievable for the MEFA.

The geographical scope of the MEFA is national. The primary motivation for this choice is, as above, the need to make the accounts compatible with the Input-Output Accounts. Since the latter are currently compiled only at the national level,[2] it is appropriate to choose this as the starting point for the MEFA. The national level is, again as above, the relevant scale at which to analyse some resource and waste flows but not others. Global warming, acid rain and ozone depletion are all waste-related issues with impacts at the national level and beyond. It is thus reasonable to analyse the waste emissions that contribute to these issues at the national level. Likewise, for natural resources that are not regionally concentrated–timber for example–the national level is an appropriate level of analysis. The national level is not most appropriate for some resource- and waste-related issues however. The wastes that contribute to urban smog, for example, are not of equal interest to all Canadians. Those who live in cities are likely to be very interested in the trends in these emissions, while rural Canadians might be less so. For the moment however, regional/local analysis of material and energy flows remains a goal for the future.

In theory, the MEFA measure all material and energy flows in the environment/economy system. In practice, it is neither possible nor desirable that the accounts be this complete. It is not *desirable* because some flows are of such little interest from an environmental perspective as to be not worth recording. The use of materials that are nearly unlimited–air for example–is one such case. It is not *possible* to be comprehensive because Canadian data representing material and energy flows are incomplete. Indeed, currently

2. Current plans call for the development of annual provincial input-output accounts by the year 1998. The only consistent, annual time-series of accounts currently available is at the national level however.

available data represent only a fraction of these flows (although the flows that are measured are among the most important). As expanded data on material and energy flows are developed, the range of materials and energy measured in the account will grow.

4.1 Rationale, uses and linkages

4.1.1 Why account for materials and energy?

The rationale for developing the MEFA rests on arguments that economic use of the environment has exceeded (or is approaching) critical thresholds. Although human degradation of the environment is not new,[1] there are both qualitative and quantitative differences between the environmental impacts of economic activity in the past and those of today. A major difference is that of scale. While the environmental degradation that occurred in ancient times was mainly localised and attributable to a few activities, today it is wide spread and associated with myriad activities. As the quote from John Evelyn in the footnote below demonstrates, England in the seventeenth century knew mainly good air quality with only isolated degraded areas. The contrast with the modern world is striking. England (and much of the rest of the earth) is no longer characterised by isolated areas of degraded environmental quality surrounded by verdant nature. Rather, the environmental effects of economic activities are felt in all corners of the planet, very often in places far removed from the source of the effect. Perhaps most worrisome is the fact that environmental systems once considered too large (the global climate) or too remote (polar regions) to be significantly affected by human activities are today under threat. Examples of the pervasive and large-scale effects of modern economic activity are easily found:

- the presence of toxic pollutants in polar regions as a result of their long-range air transport from industrial regions;
- the “death” of many lakes over eastern North America and western Europe as a result of acid rain;
- rapid, human-induced increases in the atmospheric concentrations of carbon dioxide and other “greenhouse gases”, which are likely to cause global climate change in the coming decades;
- a “hole” in the earth’s protective (and irreplaceable) ozone layer due to releases of chlorofluorocarbon (CFC) refrigerants and other gases;
- unprecedented rates of species loss due to habitat destruction and unsustainable harvest rates for renewable resources;
- the decline of important fisheries to the point of commercial inviability in many regions of the world.

Another important distinction between past economic activity and that of today is the fact that the environment has essentially no assimilative capacity for many of the waste materials released from modern economic activities. For example, the family of chemicals known as the halocarbons–best known for their role in depletion of the ozone layer–have atmospheric lifetimes that range from a few thousand to tens of thousands of years. Human activities are the sole source for releases of many of these compounds (Houghton *et al.*, 1996). The creation of such long-lived compounds means that the environmental effects of current economic activities may be felt for hundreds of years into the future.

It is clear from the above examples, and the many others that could have been noted, that economic activity has long since passed the point where the environment can be taken for granted as a source of resources and a dump for wastes. Both local and global environmental capacities to absorb wastes are being pressed upon today in unprecedented ways. Likewise, the environment’s capacity to supply the resources needed to meet the economy’s growing material demands is increasingly being exceeded. The measurement of the quantity of material and energy flows in the Canadian economy and the “intensity” with which we use the environment has thus become essential.[2] It is with this objective in mind that the MEFA have been created.

It is perhaps easier to make a case for the importance of the MEFA in terms of what they reveal about our waste flows than what they reveal about the production and consumption of resources. Most Canadians are familiar with the impacts of waste from first hand experience of air, water and land pollution. Fewer Canadians directly feel the environmental impacts of excessive resource use (although those who make their living in resource-based industries are certainly familiar with the associated economic impacts). A reasonable person might therefore ask, “Is there as compelling a reason to account for resources as there is for wastes?” Two arguments suggest there is.

First, although Canada is not in immediate danger of running out of most of its natural resources, there are certain instances where our resource stocks have been depleted almost, or completely, to extinction. The disappearance of commercially viable stocks of northern cod off the east coast is perhaps the best recent example of this. One could

1. Historians tell us that the Tiber River in Ancient Rome was badly polluted. Noxious air pollution in seventeenth century London, England was also a recognised problem. London’s air during this period was so bad that the diarist John Evelyn complained to the reigning monarch that “in all other places the Aer is most Serene and Pure, [while in London] it is Ecclipsed with such a Cloud of Sulphure, as the Sun itself, which gives day to all the World besides, is hardly able to penetrate and impart it here.” (Greenwood and Earnshaw, 1984; p. 825.)

2. In this context, intensity is taken to be the degree to which the environment is used as a source of raw materials or a sink for wastes per unit of economic output.

cite as well the near disappearance of old-growth forests across the country and the slow, but continual loss of prime agricultural land to urban development. In such cases it is important to measure both how much of the remaining resources we are consuming and how they are being consumed. Even for resources that are abundant in supply it is sensible to monitor use, particularly for non-renewable resources that will, by definition, run out one day. The MEFA are designed to provide measures of resource use that can facilitate monitoring of this sort.

The second argument in favour of measuring resource flows is related to the concerns already raised with respect to waste production. This is quite simply that the quantity of waste produced by economic activity is directly related to the quantity of raw materials and energy consumed in the first place. The basic law of conservation of mass and energy[1] demands that all material and energy entering the economy must leave it again at some point (or be permanently stored within it). Thus, any problem of excessive waste *output* is in the first place one of excessive material and energy *input*.

Often there is very little time lag between the entry of raw material or energy into the economy and its exit again as waste. Many goods (and all forms of energy) have very short life spans in the economy, becoming wastes almost immediately following their production and use. Foodstuffs and their containers, fossil fuels and many household products are all examples of such goods. Other goods are longer lived and are temporarily stored within the economic system in the form of buildings, roads, machinery and other "durable" goods. Yet even these durable goods eventually wear out become waste. There is, then, a direct link between the scale of raw material and energy used in producing goods and services and the quantity of waste produced as a result of economic activity.

There is, of course, a less direct relationship between the types of material and energy used in the economy and the wastes produced. Raw materials and energy entering the economy can undergo conversion into any of the thousands of products used by consumers. Wastes are produced all along this series of transformations, as well as when the final products themselves have served their useful lives and become waste. Simply accounting for the use of raw material and energy does not allow one to determine what all of these waste products will be. This is why the MEFA measure the flows of both resources and wastes.

Another, increasingly important, issue on which the MEFA shed light is that of recycling. Not all the wastes we produce are disposed of. More and more, wastes are diverted back into production processes through recycling programs. Although this is not a new phenomenon,[2] only recently have we seen the large-scale, institutionalised recycling programs to which most Canadians have access today. The motivation for recycling has changed as well. Whereas a material had to have significant scrap value to be recycled in the past, now the motivation for recycling is just as apt to be resource conservation and environmental protection as it is to be the search for profit. Whatever the motivation, recycling rates have increased dramatically in recent years as more and more households have gained access to curbside collection programs. Businesses and governments are also diverting an increasing amount of their solid wastes into recycling programs. Recycled waste materials produced from such programs represent direct substitutes for new (virgin) materials. Thus, their use represents a means of decreasing the raw material intensity of production; that is, reducing the quantity of virgin raw materials required per unit of production. Since the MEFA are intended to measure the material intensity of production processes, they are designed to account for the use of both recycled and virgin resources.

1. This fundamental law of science states that (except in nuclear reactions) mass and energy are conserved in all processes. That is, what goes into a system in terms of mass and energy must again come out, or else be permanently stored within the system.
2. Rag collection for paper production was common in ancient times and metals have always been recycled because of their high value.

4.1.2 Uses of the MEFA

Considerable use has already been made of MEFA data in university research projects. Other researchers accustomed to using Statistics Canada's economic data and concepts will also find the MEFA useful, as their classifications allow easy incorporation of material and energy flow data into existing models built around these concepts.

Journalists as well should find the MEFA of interest, particularly for the new context that they provide for reporting on the economy. In addition to the economic indicators that journalists are accustomed to using from Statistics Canada (GDP, unemployment rates, interest rates and so on), the MEFA now provide important environment-economy indicators that shed additional light on the nature of economic development in Canada. These are quantitative measures that define the extent to which the economy places demands on the environment as a source of raw materials and as a sink for waste materials. The indicators currently developed from the MEFA are presented in Text Box 4.1.[3]

The rationale underlying all of these indicators is, as argued above, that current material and energy flows approach or exceed those that are environmentally sustainable in the long-term. The indicators have been selected as key variables to monitor in this regard as the economy develops over time. Each one considers an important aspect of the economy's use of the environment as a source of material or as a sink for wastes. By uniting the environmental data in the MEFA with the economic data in the Input-Output Accounts, these indicators tell us how our economy is developing with respect to its demands on the environment. While they cannot themselves answer the question "What is a sustainable level of material and energy flows?" (that is a task for phys-

3. These indicators, and the technical details of their derivation, are discussed in more detail in Annex 4.2.

Text Box 4.1
Resource and Waste Indicators Developed from the MEFA

- resource intensity of industrial output
- resource intensity of household consumption
- resource intensity of net exports
- waste intensity of industrial output
- waste intensity of household consumption
- waste intensity of net exports
- renewable energy as a proportion of total energy production
- recycled proportion of total resource use

ical scientists), they can demonstrate broadly whether the economy is heading toward or away from environmental sustainability. Other things equal, if fewer demands are placed on the environment (in terms of resource and waste flows) per unit of economic output over time, the development path is leading toward sustainability. As more scientific information regarding the environment's capacities to provide resources and absorb wastes becomes available, these indicators will allow more concrete statements about the absolute environmental sustainability of the economic activity to be made.

A core set of material and energy flow indicators based on the MEFA is to be published annually–along with other economy/environment indicators developed by Statistics Canada–beginning with the first release of the CSERA in 1997. These environment-economy indicators provide important counterparts to the long-standing economic indicators published by Statistics Canada. Their creation makes it possible now to consider the development of the economy *vis à vis* our economic goals while at the same time considering the accompanying growth (or decline) in resource consumption and waste production. They allow this by answering questions of the following sort:

- what raw materials and energy are consumed by the economy, in what quantities and by whom;
- what is the "intensity" of our resource use; that is, how much raw material and energy is required to produce one unit of economic output;
- what waste products are emitted from the economy, in what quantities and by whom;
- what is the "intensity" of our use of the environment for waste absorption; that is, how much waste is released per unit of economic output;
- is resource use/waste output increasing or decreasing over time, both in absolute terms and per unit of output;
- what wastes are recycled, in what quantities and by whom; how much raw material and energy input is avoided by the use of recycled wastes?

4.1.3 Linkages to other accounts

Relationship to other components of the CSERA

Of the other major components of the CSERA described in this volume, the MEFA are most closely related to the Natural Resource Stock Accounts (Chapter 3). Indeed, the annual withdrawals of resources recorded in the Natural Resource Stock Accounts (physical versions) are carried over to the MEFA. Not all of the resource production recorded in the MEFA has a counterpart in the Natural Resource Stock Accounts however. The opposite is true as well; there are resources for which there are data in the Natural Resource Stock Accounts but no data in the MEFA. Resources for which there are only flow accounts include fish and other wild flora and fauna,[1] and water. Stock accounts for these resources have not yet been developed due to data shortcomings. As for resources for which there are stock data but no flow data, the only example is land. Although the Land Account (as described in Section 3.5) represents Canada's land area in great detail, because land is immobile there is no corresponding flow account in the MEFA.[2]

One can postulate an indirect relationship between the MEFA and the resource values measured in the monetary versions of the Natural Resource Stock Accounts, as the value of natural resources is presumably influenced by waste emissions. Forests affected by acid rain, for example, are less valuable than those that are unaffected. A relationship also exists in theory between the Environmental Protection Expenditure Accounts (Chapter 5) and the MEFA, as expenditures on equipment to abate pollution should result in measurable reductions in waste emissions. Although these relationships exist in theory, no attempt has yet been made to quantify them.

International comparisons

Canada is not alone in its development of material and energy flow accounts based on input-output accounts. National statistical agencies in several other countries–The Netherlands, Germany and Sweden in particular–have undertaken similar work.

The **Netherlands Central Bureau of Statistics** (de Boer *et al.*, 1996) has developed balances that describe in physical terms the supply and use of various materials (iron, steel, zinc and energy). From these balances they have con-

1. Flow accounts for these resources are planned for the future.
2. Land in this context refers to the surface area of the nation and not to the soil lying beneath the surface.

structed physical input-output tables that show the quantities of each material (or energy) used by industries and final consumers. Based on these tables, they then analyse the direct, indirect and total quantities of materials and energy required to produce goods and services.

The **Federal Statistical Office of Germany** (Stahmer *et al.*, 1996) has constructed a very elaborate set of input-output accounts in which all flows are measured in physical units. This differs from the approach taken in the MEFA, in which not the entire set of flows in the economy is measured in physical terms, but only the flows of specific materials and energy. The German researchers argue that complete physical input-output accounts yield analytical results superior to those possible with the combined physical/monetary data of the MEFA. They admit, however, that the cost of their production can match that of monetary accounts (several million dollars annually in the Canadian context).

In contrast, **Statistics Sweden** explicitly notes the usefulness of comparing physical data and economic data within the input-output framework. Among other measures, they suggest that this combination of physical and economic data be used to assess "trends in dematerialization" (that is, the changes in the flows of resources and wastes per unit of economic output) (Andersson, 1996). This is exactly what several of the indicators described in Annex 4.2 are intended to do.

4.2 Key concepts

Several concepts figure importantly in the presentation of the MEFA accounting framework in the following section. For the sake of clarity, these are defined and discussed here before proceeding with the discussion of the framework itself.

Economic activity is defined to include all human activity that involves the production and/or consumption of goods and services. These goods and services may be traded in the market, or they may be produced and consumed by the same economic agent. Thus, household withdrawal and use of groundwater is considered economic activity in the MEFA. This is in contrast to the Input-Output Accounts, where only production and consumption of goods and services traded in the market is recognised as economic activity.

Three categories of economic agents are recognised in the MEFA: industries, persons and governments.

Industries are groups of establishments producing the same, or similar, goods or services for sale on the market with the intention of generating profit. All industries, when taken together, comprise the business sector. Crown corporations that behave essentially like private enterprises, such as VIA Rail, are considered part of the business sector. Other public institutions (hospitals, schools, universities) that receive the major part of their funding from government and that do not operate with a profit motive are not considered part of the business sector (they are treated instead as part of the government sector).

Persons are defined as private citizens[1] in their role as consumers of goods and services *and* as non-market *producers* of resources and wastes. Again, this is in contrast to the Input-Output Accounts, in which persons are recognised only in their capacity as consumers. (Note that the terms "households" and "persons" are used interchangeably in this chapter.)

Governments are defined as either federal, provincial or municipal public administrations, agencies or organisations engaged in providing public services. These services include national defence; construction, maintenance and operation of public infrastructure (roads, sewage treatment plants and airports for example); social services (health, education and welfare) and municipal services (snow clearing and waste collection for example).

Resources, as defined in the MEFA, are the fundamental material and energy building blocks of the economy: metals, nonmetallic minerals, wood, flora and fauna (domestic and wild), water, fossil fuels and electricity. All the commodities that we consume, from clothing to food to cars, are derived in one way or another from these basic building blocks. Both the virgin forms of these materials, as well as the recycled wastes that compete head-to-head with them, are considered resources in the MEFA.

It is important to recognise that there is no requirement for material or energy to be traded in the marketplace for it to be treated as a resource in the MEFA. Both the flows of raw materials and energy produced for sale on the market as well as those produced for self-consumption are represented in the accounts.

Resources are said to be **produced** when they are extracted by an economic agent from their natural state in the environment and brought into the economy, either for subsequent sale in the market or for self-consumption by the producer. In the case of recycled waste materials, production is defined to occur when a waste material is reprocessed so that it may be used again in production activity.

Resources are said to be **consumed** when they are sold by the producer to another economic agent (either domestically or in a foreign country) *or* when they are used directly by the producer as an input into an economic activity. An example of the latter is the cooling water used in thermal electric power plants. In this case the power company is both the producer of the resource (as it is responsible for extracting the water) and the consumer of the resource (as it makes use of the water in its plant).

Waste is defined for the purposes of the MEFA as any material/energy that is of no value to the producer and that is disposed of, either directly to the environment or through another economic agent without remuneration to the producer.

1. The personal sector is defined also to include non-profit organisations (religious groups, labour unions and social clubs for example).

Waste is said to be **produced** when, in the process of engaging in economic activity, an economic agent creates material or energy for which it has no purpose and disposes of it. The waste might be formed as an unwanted by-product during a production or consumption process, or it might be a good that has served its useful life and no longer has a purpose for the owner.

Waste is said to be **consumed** by any economic agent who accepts responsibility for its disposal or who accepts it as an input into a production process. For example, when the government or the waste management industry collects waste for disposal, they are acting as a waste consumers. (Note that they are also considered to be waste *producers* when they dispose of the waste again.) Likewise, if one industry accepts the waste of another industry for direct use as a raw material input, the accepting industry is acting as a waste consumer. If no agent accepts responsibility for the waste (that is, if it is disposed of directly in the environment), then the environment is said to "consume" the waste.[1]

It is important to recognise that the term "waste" as used in the MEFA encompasses *all* types of wastes, regardless of physical form (gas, liquid, solid or some form of energy) or point of entry into the environment. This generic terminology is in contrast to the more specific terminology often used in environmental statistics. Wastes are typically referred to in the environmental literature in terms specific to the receiving environmental medium. Thus, wastes entering the atmosphere are "emissions", waterborne wastes are "effluents", and wastes that are disposed of on land are actually called "wastes" (as in solid *wastes*, hazardous *wastes*). This more cumbersome terminology has intentionally not been adopted in the MEFA. The position taken here is that the use of several terms to describes wastes is unnecessarily confusing, particularly for infrequent or new users of waste statistics.

Another point that must be emphasised about the definition of waste is that material or energy need only be valueless to its producer for it to be considered waste in the MEFA. Even material (or energy) that can be used for another purpose elsewhere in the economy is considered waste so long as it has no value for the producer. Empty aluminum beverage cans, for example, are defined as waste on the basis that they have no positive value to the beverage consumer; from her perspective, they are waste that must be disposed of. The fact that a recycling program exists through which to discard the cans does not lessen her need to do so. It simply gives her an alternative means of disposal. In the absence of such a program, she would still think of them as waste and wish to dispose of them. Only if the cans have real value for her will she choose not to discard them, but seek to use them (or sell them) instead. In this case, the cans are not waste, but valuable commodities not unlike the thousands of other commodities that are traded in the economy.[2]

1. The details of waste production and consumption are explained more fully in Section 4.3.2.

Many readers may object to the above treatment of waste on the grounds that aluminum beverage cans (and other recyclable materials) should not be labelled wastes–with all the associated negative connotations. Rather, they might argue, such materials should be viewed in a positive light as valuable resources. While this argument has a good deal of emotional appeal (no one *likes* to think of recyclables as wastes), it is cumbersome to implement from an accounting perspective. Multiple categories would be required in the MEFA framework to do so:

- recyclable wastes actually recycled;
- recyclable wastes not recycled;
- potentially recyclable wastes for which no recycling facilities exist; and
- non-recyclable wastes.

Including all these categories in the already complex MEFA framework is practically difficult. It also presents a conceptual problem in that the same material might fall into several categories at once. Returning to the earlier example, a beverage can might fall into any of the first three categories. If it is recycled, it clearly falls into the first category. But what if it is not recycled? It might be considered a "recyclable material not recycled." But it could also be considered a "potentially recyclable material for which no recycling facilities" if it is collected in a region where recycling is not practised. Then there is the problem of defining which materials are recyclable wastes and which are simply wastes. In many instances this is easily done; carbon monoxide from auto exhaust is clearly a waste, as it cannot be recycled. What about furniture? Although furnishings are in theory recyclable, in practice this is rarely done because of the cost and effort involved. So, should furniture be accounted for as non-recyclable or potentially recyclable waste? The answer is not clear.

All this is not to say that the MEFA ignores the recycling of wastes. On the contrary, **recycling** is explicitly defined in the framework as the diversion of waste materials back into the economy for reuse so that the amount of waste produced by the economy is reduced. The sale of waste material from one process for use in another process may or may not be considered recycling, depending on the circumstances. When undertaken for profit on the part of the waste producer, this type of transaction represents not the recycling of wastes but the exchange of valued goods between economic agents. It is thus outside the scope of the waste flows measured in the MEFA. However, when the sale price of waste is intended only to cover the producer's costs in the transaction, the material is considered to be a recycled waste (as it has no positive value to the producer). The argument here is that the alternative destination for this mate-

2. Note that the existence of a deposit-refund system for beverage cans does not change the nature of the cans from waste to valuable commodity. The refund associated with returning the cans simply offsets the deposit that was paid when the beverage was purchased and does not give the cans a positive value.

rial is disposal and that the transaction therefore represents the diversion of a waste back into the economy.

Units of measure

All material and energy flows are recorded in the MEFA using physical units of measure. Material flows are recorded to the extent possible using weight units (grams). Where this is not possible, volumetric units (litres) are used. Energy flows are recorded using the basic unit of measure for energy (joules). Hybrid units of measure designed specifically for reporting certain types of material and energy flows are also used where appropriate, as explained below.

Physical units are particularly well suited to material and energy flow accounting. A suitable physical unit can be found to measure any flow and it is possible, although not always practical, to measure different flows using the same unit of measure. In the case of energy, all flows can be measured using the basic energy unit, the joule. Likewise, the gram–the basic measurement unit for weight–can be used to measure any material flow. Some material flows are most appropriately measured in units other than weight however. Although scrapped cars are made up of steel, plastic, fabric, rubber and a variety of other materials, it may be difficult to measure and report the exact weight of each of these materials in each car. In such cases, it may be necessary instead to record only the number of items scrapped. In other cases, it may be more appropriate to measure material flows in volumetric units. In the case of municipal solid waste disposed of in landfill sites, for example, it is more the volume of the material that is of concern than its weight, and the most appropriate unit of measure is cubic metres (thousands of litres).

Since all material and energy flows can be measured using a single unit of measure (either the gram or the joule), summation of flows of different material or energy types is possible. Although this is possible, it is done in the MEFA only when the resulting sum is meaningful. Although there is no difference in weight between one tonne of old newspapers and one tonne of used car batteries, there is a tremendous difference in the potential environmental impact of the two as waste materials. Thus, to sum these two flows and report a release of “two tonnes of solid waste” would be to obscure the potential seriousness of these releases on their own account. In order to avoid “adding apples and oranges” like this, individual material flows are normally reported separately in the MEFA. There are, however, cases where flows of different materials (particularly wastes) can be measured on a comparable basis–and made summable–by using specifically developed weights. These allow different waste flows to be put on a comparable basis by taking advantage of similarities between the wastes in terms of environmental effects. One such unit, useful for measuring greenhouse gas emissions, is explained below to illustrate the concept.

Several different gases are responsible for the so-called greenhouse effect: carbon dioxide, methane, nitrous oxide and chlorofluorocarbons being the most important. The relative effectiveness of each of these gases at trapping heat in the atmosphere has been determined from scientific studies. The concept of global warming potential (GWP) has been developed as an index (or weight) that takes into account the relative effectiveness of each gas. Carbon dioxide, the least effective of the four at trapping heat, is arbitrarily assigned a GWP of 1; other gases are assigned values in proportion to their heat trapping power relative to that of carbon dioxide (Houghton *et al.*, 1996). GWP thus represents a weight that can be used to place greenhouse gas emissions on a common basis and allow summation of emissions. Emissions of all four of the gases can be expressed in terms of the hybrid unit of measure “carbon dioxide equivalent emissions” by multiplying actual emissions by the appropriate GWP. For example, given methane’s GWP of 21, one tonne of methane emitted is equivalent to 21 tonnes of carbon dioxide in global warming terms. By weighting all greenhouse gas emissions by their respective GWPs in this manner, it is possible to sum them to produce total “carbon dioxide equivalent emissions.”

Weights have been developed that allow other wastes to be measured in terms of hybrid units (Puolamaa *et al.*, 1996). Emissions of acid-rain causing and ozone-depleting gases, for example, can be weighted and measured on a common basis. Where possible, this process of weighting and aggregating using hybrid units is used in the MEFA, as it greatly simplifies the interpretation of the data. A major focus of the ongoing development of the accounts will be the search for hybrid measurement units and weights for other types of wastes. One category of weights that will be considered for development in the longer term is prices. By estimating the unit costs associated with various forms of wastes and using these to weight their emissions, it would be possible to measure waste flows using the same metric used for other flows in the CSNA (that is, dollars).

4.3 The MEFA accounting framework

As noted in the Introduction, the MEFA are organised around the accounting framework of Statistics Canada’s Input-Output Accounts. The modified version of this framework that serves as the basis for the MEFA is presented in Figure 4.1. In modifying the framework to make it suitable for the MEFA, several objectives were sought.

- The framework should be structured in such a way that it is suitable for recording *all* material and energy flows related to economic activity, regardless of the nature of this relationship.[1]
- The framework should represent both the production *and* consumption of materials and energy. In doing so, the traditional accounting identity between production and consumption should be respected.

1. Economic activity in this context includes all human activities associated directly or indirectly with the production or consumption of commodities.

Figure 4.1
Material and Energy Flow Accounting Framework

			A.	B.	C.	D.	E.	F.	G.	H.	I.	J.	K.	L.	M.	N.	O.
			Production of:			**Consumption by:**											
			Commodities (1... m) (monetary units)	Resources (1 ... r) (physical units)	Wastes (1 ... w) (physical units)	Industries (1 ... n)	Final demand (*F*) (1 ... f)						Waste disposal		Totals		
							Personal expenditure (1 ... h)	Fixed capital formation (1 ... k)	Net additions to inventories	Government current expenditure (1 ... g)	Exports	Less imports	To environment (1 ... j)	To disposal sites (1 ... z)	Commodities	Resources	Gross wastes
1.	**Consumption of:**	Commodities (1 ... m) (monetary units)				U	H	K	i	G	x	(m)			q		
2.		Primary inputs (1 ... p) (monetary units)				YI	YF								n		
3.		Resources (1 ... r) (physical units)				U_{ru}	H_{ru}		i_{ru}	G_{ru}	x_{ru}	(m_{ru})				r	
4.		Wastes (1 ... w) (physical units)				U_{wu}	H_{wu}			G_{wu}	x_{wu}	(m_{wu})	E	Z			w'
5.	**Production by:**	Industries (1 ... n)	V	V_{rp}	V_{wp}										g		
6.		Persons (1 ... h)		H_{rp}	H_{wp}												
7.		Governments (1 ... g)		G_{rp}	G_{wp}												
8.		Non-economic activities (1 ... t)			S												
9.	Totals	Commodities	q'			g'	e										
10.		Resources		r'													
11.		Gross wastes			w												

- All sectors of the economy should be covered in the framework. The definitions of these sectors should conform with those of the CSNA.
- The framework should facilitate the integration of material and energy flow data with the economic statistics in the Input-Output Accounts.

The elements that constitute Figure 4.1 are discussed at length below. First, a brief discussion of the reasons for adopting the input-output framework as the basis for the MEFA is warranted.

4.3.1 Benefits of the input-output framework

The benefits of using input-output accounting frameworks to analyse material and energy flows have long been recognised. Corresponding with the environmental movement of the late 1960s, several economists suggested the use of input-output techniques for environment-economy analysis (Cumberland, 1966; Daly, 1968; Isard, 1969; Ayres and Kneese, 1969; Leontief, 1970; and Victor, 1972). The work of Victor in particular has influenced the approach to material and energy flow accounting taken in the MEFA. His work represents the most comprehensive of the original frameworks and, importantly, he employed Statistics Canada's input-output accounting framework in his study.

Despite the relatively long-standing interest in the use of input-output techniques for environment-economy analysis, there was not a great deal of empirical development in the field during the 1970s and 1980s. Indeed, one of the authors cited above–noted for his contributions to the field of material and energy analysis over the last three decades–found cause to note recently that the "approach deserves much greater attention that it has received to date" (Ayres, 1996). There are several reasons why the approach is worthy of attention.

To begin with, the Input-Output Accounts are very detailed. At their most elaborate, they present production and consumption statistics for 216 industry groups, 627 commodity groups and 136 categories of final demand, in both current- and constant-dollar measures.[1] This detail is of great benefit when analysing material and energy flows. It allows one to move beyond highly aggregated measures, such as total energy use per unit of GDP, that are sometimes proposed as environmental indicators. Changes from year to year in such "economy-wide" indicators can be difficult to interpret because so many factors are at play. For example, a decrease in energy use per unit of GDP might result from a real increase in the energy efficiency of production processes, or it might result from a reduction in the contribution of energy intensive industries to the total output of the economy. Determining which factor is the actual cause is difficult. In contrast, when energy use is measured for individual industries, the effect of the changing structure of the economy is largely eliminated. A decrease in energy use per unit of GDP for the electric power industry, for example, can be interpreted unambiguously as an increase in the energy efficiency of electric power production processes.

Another reason for choosing the Input-Output Accounts as the basis for the MEFA is that they are flow accounts. This means that many of the concepts already well defined in the Input-Output Accounts are easily transferred to the MEFA (which, as their name implies, are also flow accounts). Production in the Input-Output Accounts, for example, is defined as the fabrication of goods and services for sale in the open market. It is not a significant leap to adapt this concept for use in the MEFA; three extensions suffice:

- the measurement of production must be allowed in physical units as well as monetary units;
- non-traded resource flows for self-consumption purposes must be treated as production; and
- the production of unwanted "bads" (wastes) along with the production of "goods" must be recognised.

The fact that many of the concepts of the Input-Output Accounts can be transferred to the MEFA enhances the degree to which the data from the two sets of accounts can be integrated. This, in turn, enhances the analytical power of the MEFA.

Another important benefit of linking to the Input-Output Accounts is the fact that these accounts have been produced annually by Statistics Canada for over 30 years. Moreover, since they form a cornerstone of the CSNA,[2] a great deal of effort is put into ensuring that they are as reliable, consistent and comparable as possible. Thus, the Input-Output Accounts represent a rich data set to draw on for the development of historical material and energy flow accounts. Equally importantly, Statistics Canada is committed to continued production of the Input-Output Accounts for the foreseeable future. Indeed, current plans call for the expansion of their scope to include annual provincial input-output accounts in addition to the current national versions.

Despite these strengths, one limitation of the Input-Output Accounts should be mentioned. This is the fact that the accounts are only released four years after the reference year.[3] This delay is explained by two factors. One is simply their complexity–the enormous detail they present demands a long time to amass. The other is the aforementioned fact that the Input-Output Accounts are used as

1. The accounts are actually produced at three different levels of aggregation. Many data at the most detailed level are not publicly available, as the legal requirement to protect respondents' confidentiality prevents their release. Thus, the accounts are released to the public at the so-called "medium" level of aggregation, which shows 50 industries, 100 commodities and 28 categories of final demand. At this level of aggregation, all of the data are non-confidential.

2. The Input-Output Accounts are used as the benchmark estimate of GDP to which all other estimates of GDP in the CSNA must accord.

3. Current plans call for the shortening of the production period for the Input-Output Accounts from fours years to two by the 1998 reference year.

Statistics Canada's benchmark estimate of GDP. Because they represent the "final word" on GDP, the Input-Output Accounts cannot be completed until the most detailed source data are available in final form. In the case of some sources (income tax files for example), this can take several years. The delay in releasing the Input-Output Accounts means that the MEFA cannot be used for analysis of material and energy flows within the last four years. Of course, it is possible to compile material and energy flow data for more recent years, just not to combine these data with input-output data.

4.3.2 Elements of the framework

It is immediately obvious upon seeing the MEFA framework in Figure 4.1 that several new rows and columns have been added to the standard input-output framework. The new rows and columns are shaded in Figure 4.1 to distinguish the environmental component of the framework from the economic component remaining from the Input-Output Accounts. Each new row and column contains a number of new matrices and vectors defined to represent resource and waste flows. To aid in the discussion of these elements, columns in Figure 4.1 have been labelled with letters–and rows with numbers–so that cells in the table may be referred to by their co-ordinates.

The business sector in the MEFA

Matrix V_{rp}[1] (cell B5 in Figure 4.1) represents the resource production of industries. This matrix, which has dimensions n x r, shows the physical quantity of each resource[2] produced by each industry in a given year. Matrix V_{rp} can be thought of as the resource equivalent of the make matrix (*V*) defined for economic commodities in the Input-Output Accounts (see Figure A4.1 in Annex 4.1). Indeed, many of the same flows that are recorded in monetary units in matrix *V* are recorded in physical units in matrix V_{rp}. Wood production by the forestry industry, for example, is recorded in both matrices. There is a fundamental difference in the way that resource production is treated in these two matrices however.

While the (monetary) make matrix records production only for those resources that are bought and sold on the market, the (physical) resource production matrix records the production of both traded and self-consumed resources. Taking wood as an example, this means that the timber harvested by forestry companies as well as the firewood harvested by households are recorded in the resource production matrix. In contrast, firewood harvested and consumed directly by households is excluded from the make matrix because no market transaction occurs as a result of this activity. Both traded and untraded resource flows must be included in matrix V_{rp} if the MEFA are to account for all material and energy flows in the economy. In general, untraded resource flows are small in comparison to their traded counterparts, as most resources are produced for sale on the market. In the case of water however–a lot of which is extracted directly by users–untraded flows are substantial relative to traded flows. If untraded water flows were excluded from the MEFA, this would lead to serious under-reporting of total water flows in the economy.

The treatment of the waste management industry in the resource production matrix deserves special mention.[3] While this industry does not produce any virgin resources, it does produce recycled waste materials that often compete head-to-head with virgin resources. These recycled wastes are considered resources in the MEFA framework and their production by the waste management industry is recorded in matrix V_{rp}.

Turning to the business sector's resource consumption, matrix U_{ru} (cell D3 in Figure 4.1; dimensions r x n) has been defined to represent the physical quantity of each resource used by each industry in a given year. It is important to note that not only domestically produced resources are represented in this matrix, but imported resources as well. Use of recycled waste materials that act as substitutes for virgin resources is also recorded in matrix U_{ru}. Thus, all resource consumption by industries, regardless of source, is recorded here. Furthermore, as just explained with respect to the resource production matrix (V_{rp}), the resource use matrix records the consumption of both traded and non-traded resources. Self-supplied irrigation water, for example, appears as resource consumption by the agriculture industry in matrix U_{ru}.

Matrices V_{rp} and U_{ru} are sufficient to record the *resource* flows associated with industrial activity. Resources represent only one dimension of the MEFA however; new matrices are also defined to represent industrial *waste* production and consumption.

Matrix V_{wp} (cell C5 in Figure 4.1; dimensions n x w) represents the physical quantity of each waste produced by each industry in a year. It is useful to recall the definition of waste presented on page 71 before discussing this matrix further:

> **waste** is any material/energy that is of no value to the producer and that is disposed of, either directly to the environment or through another economic agent without remuneration to the producer.

From this definition, it is clear that all industrial waste production must be recorded in matrix V_{wp}, regardless of how the waste is dealt with following production. Even if the waste is used as an input by another industry, or sent for re-

1. A subscript "rp" in the MEFA framework indicates a matrix or vector representing resource production. Similarly, subscripts "ru", "wp" and "wu" indicate matrices or vectors that represent resource use, waste production and waste consumption respectively.
2. The basic resource categories for which data are recorded in matrix V_{rp} are metals, nonmetallic minerals, wood, flora and fauna (domestic and wild), water, fossil fuels and electricity. The full resource classification used in the MEFA is presented and discussed in Section 4.3.4.
3. The waste management industry is made up of those establishments engaged in the collection, treatment, recycling and disposal of wastes produced by other economic agents. It forms part of the "Other Utilities Industry" in the MEFA industrial classification.

cycling, so long as there is no financial gain to the waste producer as a result, this flow is recorded as waste production by the producing industry. Thus, matrix V_{wp} gives a picture of the total waste production associated with each industry's activity "at the plant gate."

Again, the treatment of the waste management industry in this matrix deserves special mention. Because this industry collects wastes for treatment and disposal from other waste producers (industries, households and governments), the wastes it produces are of two types. First, there are those that result from the waste management industry's own activities (exhaust emissions from waste collection vehicles for example). Then there are the wastes that it produces as a result of collecting and disposing of other producers' wastes. The latter wastes may be identical to those collected by the waste management industry (in the case of wastes for which pre-disposal treatment is not required), or they may differ in form and quantity from the wastes collected (if the wastes require treatment prior to disposal). In order to avoid double counting these wastes in the calculation of the industrial waste intensity indicator mentioned in Text Box 4.1,[1] the two waste streams produced by the waste management industry are recorded separately in matrix V_{wp}.

Considering now the consumption of wastes by industries, Matrix U_{wu} (cell D4; dimensions w x n), is defined to represent the annual use of each waste by each industry. The waste use recorded in this matrix is of two sorts. In the case of all industries except the waste management industry, it is the direct use of waste materials as raw material inputs; the use of fly ash from the electric power industry in the production of cement is a good example. (Recall, however, that such use must be without financial gain to the waste producer for it to be considered waste consumption in the MEFA.) In the case of the waste management industry, waste use is defined as the collection of other agents' wastes for treatment and disposal. So that the quantities of wastes collected for recycling may be tracked in the MEFA, this use is split into two categories: wastes collected for treatment and disposal, and wastes collected for recycling.

It is important to recognise that the use of recycled wastes is not recorded in matrix U_{wu}. As mentioned above, recycled wastes are considered resources in the MEFA framework, and their use is therefore recorded in the matrix of resource use (U_{ru}).

Households and governments in the MEFA

While households and governments are seen exclusively as *consumers* in the Input-Output Accounts (because they do not produce commodities for the market), in the MEFA they are treated as both *consumers* and *producers*. It is essential that they be included in both the production and consumption portion of the MEFA, as they are major producers and consumers of both wastes and resources.

1. See Annex 4.2 for details of this calculation.

Matrix H_{rp} (cell B6), with dimensions h x r, represents the production of resources by households.[2] This production, while generally small in comparison to that of the business sector, is significant in some cases. It includes, for example, the harvesting of wood for firewood and the direct extraction of water for household use. Because households do not produce a large number of resources on their own account however, matrix H_{rp} will be very sparse (that is, it will have many zero entries).

Further down column B in cell B7, matrix G_{rp} (dimensions g x r) represents the production of resources by various levels of government.[3] As with households, government production of resources is relatively minor. It is significant, however, in the case of water extracted for municipal supply. Government production of recycled waste materials is also recorded in matrix G_{rp}.

Turning to the consumption of resources by households and governments, these are shown in matrices H_{ru} (cell E3; dimensions r x h) and G_{ru} (cell H3; dimensions r x g) respectively. Again, the direct consumption of resources by persons and governments is relatively small except in the case of water. Most other resources they consume come indirectly in the form of finished goods purchased from the business sector (for which the original resource consumption is recorded in matrix U_{ru}). As with industries, it is not just the consumption of domestically produced resources by persons and governments that is represented in matrices H_{ru} and G_{ru}, but also any consumption of imported resources that occurs within these two sectors.

Waste production by households is treated similarly to their resource production. Matrix H_{wp} (cell C6; dimensions h x w) is defined to represent the annual production of wastes from households. This production includes all wastes associated with household consumption activities, from automobile exhaust emissions, through kitchen waste to sewage and worn-out household appliances.

Government waste production is recorded in matrix G_{wp} (cell C7; dimensions g x w). Governments are similar to the waste management industry in that they produce wastes on their own account, as well as producing wastes as a result of the collection and disposal of wastes produced elsewhere in the economy. These two waste streams are recorded separately in matrix G_{wp} in order that the waste production directly associated with government activities may be distinguished from the wastes governments produce in their waste management capacity.

Consumption of wastes by households and governments is represented in matrices H_{wu} (cell E4; dimensions w x h)

2. The classification of household production used in the MEFA is identical to that used for household expenditure in the final demand matrix of the Input-Output Accounts. Production of firewood for own-use by persons, for example, is classified to a category called "Other fuels" in the MEFA, which is the same as category used to record purchases of firewood in the Input-Output Accounts.
3. As with persons, the same classification of government activities is used in the production portion of the MEFA as is used in the final demand portion of the Input-Output Accounts.

and G_{wu} (cell H4; dimensions w x g) respectively. In the case of households, waste consumption is limited to the backyard composting of kitchen and yard wastes. Government waste consumption represents the collection and disposal of wastes from households and businesses. As with waste consumption by the waste management industry, government waste consumption is split into two categories in matrix G_{wu}: wastes collected for disposal and wastes collected for recycling.

Imports and exports

Resources (wastes) produced in Canada are often shipped abroad for use (disposal). The reverse is also true; Canadian companies often import resources (wastes) produced elsewhere for use in their own production processes (disposal/recycling here in Canada). These imports and exports represent a portion of the total resources and wastes entering and leaving the economy and, as such, must be included in the MEFA accounting framework.

Vector x_{ru} (cell I3; dimensions r x 1) represents the resource exports from the Canadian economy to the rest-of-the-world. Vector m_{ru} (cell J3; dimensions r x 1) represents the flows of resources in the opposite direction; that is, Canadian resource imports from the rest-of-the-world.

Vector x_{wu} (cell I4; dimensions w x 1) represents exports by Canadian companies of waste for disposal/recycling in other countries. Vector m_{wu} (cell J4; dimensions w x 1) represents the wastes produced in other countries imported into Canada for disposal/recycling by domestic industries.[1]

Waste disposal

Up to this point, several ways in which wastes are consumed in the economy have been mentioned (use by industry, use by households and governments and exportation). However, the most important form of waste consumption has only been mentioned in passing to this point. This is waste disposal.

Wastes that are disposed of face one of two fates. One is release into the environment through the air, water or land. This is the fate of a great deal of our wastes, including all gaseous and most liquid wastes. Solid wastes, in contrast, are not usually dumped haphazardly in the environment, but are disposed of instead in some form of controlled or contained site. This might be as simple as an open-pit landfill or it could be as sophisticated as a nuclear waste storage facility.

The post-disposal environmental and human health effects of a given waste will vary according to the how it is disposed of. For example, the impact of a chemical discharged into a river system will be concentrated in the downstream aquatic and human environments. The same chemical released into the air will affect completely different environments over a potentially much wider area. It is important that the MEFA acknowledge these differences by allowing waste disposal to be classified according to the medium in which it occurs.

Two general classes of disposal media are represented in the framework: the “environment” and “disposal sites” (columns K and L). The latter are defined as repositories into which waste is discarded for permanent (or long-term) storage. Landfill sites, mine tailings piles and spent nuclear fuel rod stores are all examples of waste disposal sites. Disposition of wastes into these sites is recorded in the framework in matrix Z (cell L4; dimension w x z), which represents the physical quantity of each waste disposed in each type of site annually.

Wastes that are not disposed of in managed disposal sites are, by definition, disposed of in the environment. This implies that the environment includes everything that is not a managed waste disposal site. This rather broad definition takes in all the aspects of the natural world that we normally think of as comprising the environment (oceans, rivers, forests, the atmosphere, etc.), plus parts of the human environment not normally thought of in this way; agricultural land, urban spaces, and road networks for example.

The environment is represented as comprising “j” sub-categories in Figure 4.1. The value of j might be very high, as it is possible to subdivide the physical environment into many components. At the most basic level, air, land and water are used to define the environment in the MEFA (the full classification of the environment used in the MEFA is presented in Text Box 4.4).

Waste disposal in the environment is represented in Figure 4.1 by matrix E, (cell K4; dimension w x j), which represents the annual quantity of each waste type disposed in each of the j components of the environment.

Resource inventories

Resources (but not wastes) are often held in inventories for some period of time before being sold for further processing. In order that the equality between resource supply and demand be respected in the MEFA, changes in resource inventories must be accounted for in Figure 4.1. Vector i_{ru} (cell G3; dimensions r x 1) shows the net annual physical additions to resource inventories. Inventories can represent both a source of resources–if net additions are negative–or a disposition of resources–if net additions are positive.

Other sources of waste

As mentioned at the beginning of Section 4.3, the MEFA are intended to comprehensively account for material and energy flows associated with economic activity. To achieve this goal with respect to wastes, two broad classes of waste materials must be defined: 1) wastes directly associated with economic activity in the current time period and 2) wastes associated with economic activity, but not directly attributable to the current time period. The first class of waste emissions–those associated with current economic activities–

1. Resource and waste imports are recorded as negative values in the MEFA, as they represent sources of materials and energy to the domestic economy rather than consumption of domestically produced materials and energy. That is, they represent *negative* final demand for materials and energy.

are covered by the waste production matrices that have been defined up until this point. The treatment of the second class remains to be described.

The most important example of the second category of waste is what can be termed “durable-good waste.” This is the waste created when long-lived goods (i.e. those with lifetimes of more than one year) are disposed of. The quantity of such goods disposed of in the current time period is not a function of current economic activity, but of the amount of goods accumulated from purchases made in years gone by. It would be incorrect to combine this waste production with that truly related to current activity. Doing so would limit the usefulness of the MEFA for analysing the relationship between current activity and the associated waste production. To avoid confounding these two classes of wastes, durable-good wastes are recorded independently in the MEFA framework. As the details of this treatment are lengthy, they are presented separately below in Section 4.3.3.

Two other important sources of waste that are associated with economic activity but not directly attributable to current activities exist. These are the wastes associated with catastrophic spills[1] and those associated with leakages from waste disposal sites.[2] In the case of catastrophic spills, there is a probabilistic relationship with economic activity over long periods of time, but the events themselves are random. Thus, they should not be attributed solely to the economic activity in the period in which they occur. Likewise, the wastes that leak out of storage sites are associated with the accumulation of wastes in storage sites over long periods of time. Again, it would be wrong to attribute these leakages only to the economic activity during the period in which the leakage occurs.

Since none of the waste sources discussed above have any relationship to current economic activity, they are not recorded along with the wastes that are related to current activity in the MEFA. Instead, matrix *S* (cell C8; dimensions t x w) has been defined to represent the annual quantity of wastes produced by “t” sources other than current economic activities. The classification of these waste sources is presented below in Section 4.3.4.

Total material and energy flows

The final elements that remain to be defined in Figure 4.1 are vectors *r* and *w* (and their transposed counterparts *r´* and *w´*), which represent the total flows of domestically produced resources and wastes respectively.

Total use of domestically produced resources is represented in the framework by vector *r* (cell N3, dimensions r x 1), which shows the annual domestic consumption of each resource. This can be expressed algebraically as:

$$r = \sum_{n} U_{ru} + \sum_{f} (H_{ru} + i_{ru} + G_{ru} + x_{ru} - m_{ru}) \qquad \text{Eq. 4.1}$$

Total domestic resource production is represented by vector *r´* (cell B10; dimensions 1 x r). This vector is just the transpose of vector *r*, as the production and consumption of resources are by definition equivalent.

Total waste production in the economy is represented in the framework by vector *w* (cell C11; dimensions 1 x w), which represents the gross annual production of each waste from all domestic sources. It is important to note that production of wastes is measured in vector *w* on a gross basis and, therefore, includes a substantial amount of double counting. This is because the same waste production can be recorded more than once in the framework. The production of a given household waste, for example, can be recorded twice, once as waste output of households and then again as waste output of governments (if it is simply collected and disposed of without treatment). In order to calculate net waste production (NWP), it is necessary to subtract all waste use for economic purposes (net of imported wastes) from gross domestic waste production:

$$\text{NWP} = w - \left(\sum_{n} U_{wu} + \sum_{f} [H_{wu} + G_{wu} + x_{wu} - m_{wu}] \right) \qquad \text{Eq. 4.2}$$

The difference between gross and net waste production is the waste that is diverted back into the domestic economy as a result of recycling and other waste reuse activities. Net waste production is the amount that is disposed of in managed disposal sites or in the environment.

At this point, all of the elements of Figure 4.1 have been defined and discussed. To summarise, the following elements have been defined to represent annual material and energy flows in the economy-environment system:

- matrix V_{rp} (n x r) - resource production by industry;
- matrix U_{ru} (r x n) - resource consumption by industry;
- matrix V_{wp} (n x w) - waste production by industry;
- matrix U_{wu} (w x n) - waste consumption by industry;
- matrix H_{rp} (h x r) - resource production by persons;
- matrix H_{ru} (r x h) - resource consumption by persons;
- matrix H_{wp} (h x w) - waste production by persons;
- matrix H_{wu} (w x h) - waste consumption by persons;
- matrix G_{rp} (g x r) - resource production by governments;

1. Catastrophic spills are very large spills that occur on a random basis; oil tanker disasters are a good example. Although such spills show a probabilistic relationship with economic activity over long periods of time, the events themselves are random in any given time period.
2. Waste disposal sites are often themselves sources of wastes emissions because they are never perfect storehouses. Moreover, the wastes that escape are often not the same as the wastes that are stored, as chemical and physical transformations can take place within the site. Indeed, these transformations are themselves often the cause of the leakages. In the case of landfill sites, for example, the action of bacteria on buried organic material results in the production of methane gas that bubbles up through the waste pile and leaks into the atmosphere.

- matrix G_{ru} (r x g) - resource consumption by governments;
- matrix G_{wp} (g x w) - waste production by governments;
- matrix G_{wu} (w x g) - waste consumption by governments;
- matrix S (t x w) - waste production from sources not related to current economic activity;
- vector i_{ru} (r x 1) - net change in resource inventories;
- vector x_{ru} (r x 1) - resource exports;
- vector x_{wu} (w x 1) - waste exports;
- vector m_{ru} (r x 1) - resource imports;
- vector m_{wu} (w x 1) - waste imports;
- matrix E (w x j) - disposal of wastes directly to the environment;
- matrix Z (w x z) - disposal of wastes into waste disposal sites;
- vector r (r x 1) - total consumption of resources;
- vector w' (w x 1) - gross consumption of wastes;
- vector r' (1 x r) - total production of resources; and
- vector w (1 x w) - gross production of wastes.

4.3.3 Treatment of durable-good wastes

In the Introduction to this chapter, it was explained that one of the uses of the MEFA is to monitor how waste output is changing over time, both in absolute terms and per unit of economic output. The goal of such a measure is to track the evolution of the economy to see whether we are becoming less "waste intensive"–that is, to see if we produce more goods with fewer wastes as time goes by. To measure this, it is necessary that the waste flow data in the MEFA be directly comparable with the economic data in the Input-Output Accounts. This said, it is important to recall here that the Input-output Accounts measure *current economic activity* only. That is, they measure the production and consumption that occur in a single accounting period of one year's duration. If waste data from the MEFA are to be comparable with data from the Input-Output Accounts, then the former must also be associated only with economic activity during a single year. Here is where the difficulty with durable goods presents itself; there is no direct association between the quantity of durable goods discarded in a given year and the economic activity recorded for that year in the Input-Output Accounts.

Durable goods such as refrigerators, furnishings, automobiles, machinery, buildings and other infrastructure typically have useful lives of more than one year. There is then usually a time lag between the accounting period in which a durable good is purchased and the period in which it ultimately becomes waste. This means that the quantity of durable goods discarded in a given year is a function of the quantity of such goods amassed from purchases in *earlier* years, not the year at hand. To give an example, the number of taxicabs scrapped in a year is only weakly related to that year's taxi industry output as recorded in the Input-Output Accounts. It is strongly related, on the other hand, to the size and age-structure of the stock of taxis resulting from purchases of cabs in earlier periods. To associate the current disposal of old cabs entirely with current taxi industry activity would misrepresent the waste production truly associated with the industry's current activity. This would limit the analytical usefulness of the MEFA by obscuring the relationship between current activity and the properly associated waste production. The remainder of this section describes the treatment of durable goods that is proposed to avoid this problem.[1]

Durable-good wastes in the business sector

Businesses account for the cost of their capital (or durable) goods over the entire lifetime of the goods. These items contribute to production in many time periods, so it is sensible that production in each of those time periods should bear its share of the original cost of the item. In each year that a good is in use then, accountants charge a certain portion of its original value against that year's profits. For example, if the good has a lifetime of ten years, one tenth of its value might be charged against profits in each of the ten years the good is in service. In this way, profits in the year of purchase are not made to bear the full original cost of the capital item.

In the same vein, an argument can be made that the waste associated with the ultimate disposal of durable goods should be distributed among each of the periods in which the goods are employed. Taking our good with a life span of ten years again, one tenth of the waste ultimately associated with the disposal of this good could be attributed to each of the years in which it is used. There are several reasons why such an approach is appealing.

First, the idea that a portion of the waste associated with the disposal of durable goods should be attributed to production in each period in which the goods are used seems just. This is particularly true when the life of the good is such that it stretches between generations. Treatment of durable goods on this basis ensures that economic activity–and the current generation that enjoys its benefits–is "held responsible" for its share of the waste that will ultimately result, perhaps far in the future, from the disposal of the capital it employs.

Second, the comparability of the MEFA and the CSNA is enhanced when durable goods are treated in a parallel fashion with respect to both economic depreciation and waste production. Industrial activity as measured in the Input-output Accounts implicitly includes a value for capital

1. The treatment is referred to as "proposed" because it is as yet an empirically untested concept.

depreciation. This value represents the "amount" of capital used up, or depreciated, by the industry during the accounting period. If the waste that is ultimately associated with the disposal of capital assets is also distributed over the period of their use, then waste production measured in the MEFA is made more comparable with the industrial activity measured in the Input-Output Accounts.

To give an example of how the accounting of durable-good waste on this basis could work, consider a purchase by industry ABC today of 100 units of capital good X. Assume that X has a useful life of 10 years. Ten years hence the industry will dispose of this asset, creating 100 units of waste X. In the span of those 10 years, the industry makes continual use of the capital asset in its production processes. Using a straight-line schedule of "waste accumulation," one tenth of the waste associated with this asset's ultimate disposal (10 units) is attributed to industry ABC in each of the 10 accounting periods.

This yearly "production" of waste would be represented in the MEFA as an entry of 10 units of waste X in special matrix devoted to recording durable-good waste production. The "disposal" of each year's incremental waste is recorded in matrix *Z* in a column labelled "accumulated durable-good waste inventory." Of course, no such inventory exists in reality; it is simply an accounting construct where the accumulated (but not yet disposed) durable-good waste is held until the good is actually discarded. When real disposal does take place in year 10, the MEFA shows a flow of 100 units of waste X from the "accumulated durable-good waste inventory." This is offset by the consumption of 100 units of waste X appearing elsewhere in the account, either as an input to recycling (matrix U_{wu}), as disposal in the environment (matrix *E*) or as final disposal in a managed disposal site (another column in matrix *Z*). Accounting for durable-good waste in this way serves the dual purpose of justly distributing durable-good waste to production activity over all periods in which the capital is employed, as well as recording the actual waste flow when the capital item is discarded.

Durable-good wastes in the personal sectors

The treatment of durable goods proposed for the business sector is not directly applicable to persons. Although persons do use durable goods, their consumption of such goods is not capitalised in the Input-Output Accounts. Rather, purchases of long-lived assets by persons are treated entirely as current consumption in the period of purchase. Thus, linking the wastes associated with future disposal of durable goods to the value of personal expenditure in the each period leading up to disposal is not possible.

The alternative treatment proposed for durable-good wastes in the personal sector is to record the *total* waste associated with the ultimate disposal of durable assets in the period in which they are purchased. This way, the MEFA would show the total waste associated with personal expenditure during each accounting period. This would include waste associated with nondurable goods (combustion emissions from home heating fuel for example) as well as the future waste attributable to the purchases of durable goods during the period. In this way, the treatment of personal expenditure in the Input-Output Accounts and the treatment of the associated waste production in the MEFA are on an equal footing. Interperiod equity is served as well, as the future waste burdens associated with current levels of personal expenditure are clearly represented in the account.

As with industries, personal waste "production" from durable goods would be represented in the MEFA in a matrix specially created for this purpose. The actual production of wastes from persons during an accounting period would continue to be recorded in matrix H_w. The "disposal" of the durable goods in the period of purchase would be shown in the same "accumulated durable-good waste inventory" mentioned above with respect to industries. At the point when an asset is actually discarded, the account would record a decrease in the durable-good waste inventory equivalent to the quantity of waste generated by the good and a corresponding increase in waste disposal to another destination (recycling, the environment or a managed disposal site).

Durable-good wastes in the government sector

Rather than being treated as current consumption, as is the case for persons, government purchases of durable goods are capitalised in the Input-output Accounts. Nevertheless, the treatment of government durable-good wastes cannot be the same as that for industries. There is no implicit capital depreciation for government shown in the Input-Output accounts, the absence of which means that (like persons) government purchases of durable goods appear in the accounts only in the period of purchase (as capital formation instead of current consumption).Thus, since the treatment of government purchases of durable goods has more akin with the treatment given of such purchases by persons, the same treatment of durable-good wastes proposed for persons is also the proposed treatment for governments.

Estimating durable-good wastes

In order to implement the treatment of durable-good wastes proposed above, the quantities of such wastes "produced" during each accounting period must be estimated in some manner. To do so, information about the expected lifetime of durable goods and a choice of waste accumulation rate for each type of good is needed. Expected lifetimes for durable goods pose no problem, since they are already established by Statistics Canada for the purposes of calculating economic depreciation. The simplest choice of waste accumulation rate is simply the inverse of the expected lifetime expressed as a percentage. Using this rate, an equal amount of waste is "produced" in each year of an asset's expected life, so that in the final year the accumulated amount is exactly equal to the actual amount of waste generated when the asset is discarded. Other assumptions about waste production rates are also possible. One could argue, for example, that waste should be accumulated at a higher rate in later years of the asset's life, on the basis that as goods age they have an increasing likelihood of being discarded.

Difficulties with durable-good waste accounting

There are many problems, both conceptual and practical, with the treatment of durable-good wastes proposed for the MEFA. A serious conceptual problem is that of timing: what to do when there is a discrepancy between the expected lifetime of an asset and the actual period that a given example of that asset is used in the economy. In such a case, the durable-good waste production recorded in the MEFA would lag or precede the actual waste produced in the economy.

Another conceptual problem is the inconsistency in the treatment of durable-good wastes between the business sector and the household and government sectors. Ideally, one would like the production of durable-good wastes from all sectors of the economy to be treated in the same fashion in the accounts. This would enhance the comparability of waste data between the three sectors. However, the inconsistent treatment of durable-good purchases in the Input-Output Accounts requires that the associated wastes be accounted for in an inconsistent fashion as well. Otherwise, the economic data in the Input-Output Accounts and the waste data in the MEFA would not be comparable. Comparability of economic and environmental data is considered more important in this case than comparability of environmental data for different sectors.

As for practical shortcomings, the most serious is quite simply that the data that are needed to implement the proposed methods are not available. In particular, data on the mass of durable goods extant in the economy and those produced and discarded in each accounting period are required; such data are not currently available.

For the time being, special treatment of durable goods in the MEFA along the lines proposed here remains a goal for the future. Any disposal of durable goods for which data are currently available will simply be recorded in the MEFA along with the other wastes produced by industries, persons and governments.

4.3.4 Classifications

Effective classifications are essential in all accounting frameworks, including the MEFA.[1] To begin with, they facilitate the organisation of accounts by providing unambiguous rules for the incorporation of data. As well as aiding the accountant in constructing accounts, good classifications also benefit the user. Once users become familiar with the classifications used in a given accounting framework, they can rely on them to direct them quickly and easily to the data they require. Effective classifications also ensure that accounts compiled in different time periods–or by different people–are comparable with one another, something that is very important to users interested in examining intertemporal trends. In short, an ideal classification is one that is:

- flexible enough to meet the needs of many different users;
- complete, in the sense that it covers all relevant aspects of the subject matter that it is intended to classify;
- easily understandable by all those who are likely to make use of it; and
- non-ambiguous, in the sense that all elements of the subject matter in question fit into the classification in one place and one place only.[2]

The classifications used in the MEFA have been developed with the above goals in mind. The subject matter for which classifications are required are:

- industries;
- commodities;
- final consumption categories;
- resources;
- wastes;
- waste disposal routes; and
- non-economic sources of wastes.

As already mentioned, the MEFA use the same classifications of industries, commodities and final consumption categories that are used in the Input-Output Accounts (Statistics Canada, 1987). Classifications for the remaining areas have been developed specifically for use in the MEFA. These are presented and discussed below.

Resource classification

The resource classification used in the MEFA is presented in Text Box 4.2. As space precludes presentation of the complete classification, only the main headings and subheadings are shown. The complete classification contains further subdivisions that allow more detailed resource-use statistics to be classified.

As mentioned earlier in this chapter, the MEFA are intended to cover all of the resources used in the economy, including recycled wastes that act as substitutes for virgin resources. The resource classification has been developed to reflect this goal. It is structured so that all resources that Canadians extract from the environment can be unambiguously classified.

1. Classifications are defined as systematic arrangements of data classes pertaining to a particular subject matter into groups or categories according to established criteria.

2. For a more detailed discussion of classification issues see Statistics Canada (1980).

Text Box 4.2
Resource Classification

1 Soil

2 Sub-soil resources
- 2.1 Crude petroleum
  - 2.1.1 Conventional
  - 2.1.2 Non-conventional (tar sands)
- 2.2 Natural gas
- 2.3 Natural gas liquids
- 2.4 Coal
  - 2.4.1 Lignite coal
  - 2.4.2 Sub-bituminous coal
  - 2.4.3 Canadian bituminous coal
  - 2.4.4 Imported bituminous coal
  - 2.4.5 Anthracite coal
- 2.5 Metals
  - 2.5.1 Copper
  - 2.5.2 Nickel
  - 2.5.3 Zinc
  - 2.5.4 Lead
  - 2.5.5 Gold
  - 2.5.6 Silver
  - 2.5.7 Molybdenum
  - 2.5.8 Uranium
  - 2.5.9 Iron
  - 2.5.10 Other metals
- 2.6 Non-metals
  - 2.6.1 Nitrogen
  - 2.6.2 Phosphorus
  - 2.6.3 Potassium
  - 2.6.4 Sulphur
  - 2.6.5 Chlorine and other halogens
  - 2.6.6 Other non-metals
- 2.7 Non-metallic minerals
  - 2.7.1 Salt
  - 2.7.2 Potash
  - 2.7.3 Limestone
  - 2.7.4 Sand and gravel
  - 2.7.5 Gypsum
  - 2.7.6 Other non-metallic minerals

3 Bio-resources
- 3.1 Wood
  - 3.1.1 Hardwood
  - 3.1.2 Softwood
- 3.2 Marine resources
  - 3.2.1 Pelagic fish
  - 3.2.2 Ground fish
  - 3.2.3 Crustaceans and molluscs
  - 3.2.4 Other marine resources
- 3.3 Terrestrial flora and fauna
  - 3.3.1 Wild
  - 3.3.2 Domestic

4 Water
- 4.1 Fresh, self-supplied
  - 4.1.1 Surface
  - 4.1.2 Ground
- 4.2 Fresh, publicly-supplied
  - 4.2.1 Surface
  - 4.2.2 Ground
- 4.3 Brackish
- 4.4 Salt

5 Energy
- 5.1 Coal
- 5.2 Crude oil
- 5.3 Natural gas
- 5.4 Liquid petroleum gases
- 5.5 Electricity
- 5.6 Coke
- 5.7 Refined petroleum products
  - 5.7.1 Motor gasoline
  - 5.7.2 Diesel fuel
  - 5.7.3 Aviation fuel
  - 5.7.4 Light fuel oil
  - 5.7.5 Heavy fuel oil

6 Recycled wastes
- 6.1 Recycled ferrous metals
- 6.2 Recycled aluminum
- 6.3 Other recycled non-ferrous metals
- 6.4 Recycled water
- 6.5 Recycled wood fibre

Although the classification is straightforward, the treatment of energy commodities requires some explanation. At first glance, it may seem odd that many energy commodities are mentioned twice in the classification, once under subsoil resources (category 2) and again under energy (category 5). This is done because both the physical quantity of these commodities consumed (in volume or weight units), as well as the energy provided by these commodities (measured in joules) are recorded in the MEFA. The classification reflects this fact. For example, category 5.1 (coal energy) does not represent coal as a physical entity (this is classified in category 2.4), but the energy provided through the consumption of coal.

Waste classification

The waste classification used in the MEFA is shown in Text Box 4.3. In developing this classification, chemical structure has been taken as the basic criterion for organising wastes.[1] That is, wastes that are similar in terms of their chemical make-up are grouped together in the classifica-

1. In the case of energy chemical structure does not apply. Energy is simply classified according to the three forms in which it commonly flows.

tion. Again, limited space restricts the presentation to only the top-level categories and to the more important sub-categories. Each of the categories in the classification is further divided for use in classifying more specific waste flows. For example, paper (category 1.7.3) is divided into: newsprint, magazines, fine paper, cardboard and boxboard.

One of the difficulties in classifying wastes is that they are often not homogenous and, therefore, not easily classified unambiguously. Wastes that are mixtures or composites[1] of unknown or partially known composition present a problem in a classification based on chemical structure. These types of wastes are dealt with in one of two ways.

If the composition of a heterogeneous waste is known, it is in general classified according to its constituent components. Waste gases from fossil fuel combustion, for example, are reported in terms of their component gases, rather than as “fossil fuel combustion gases”. If the composition is not known, the waste is classified as a mixture or composite waste.

An argument can be made that some heterogeneous wastes should be classified as mixtures or composites even if the composition of the waste is known. This argument rests on the idea that the environmental impact of a given heterogeneous waste is not necessarily a function of the impact of each of the components of the waste individually. If this were always the case, then it would always be better to report heterogeneous wastes in terms of their components (when they are known). It is not always the case that the environmental impact of a heterogeneous waste is the sum of the impact of its components however. In some cases there can be interactions between the components that serve to increase the impact of a mixture or composite beyond what would be the impacts of its components individually. For example, an acidic sludge containing minerals with heavy metal content may be more damaging than just the minerals or acid in isolation if the heavy metals are liberated by the presence of the acid. This argues in favour of reporting some heterogeneous wastes as such even when their composition is known in detail. Clearly, there is no single, fully acceptable manner of treating heterogeneous wastes in the MEFA. All that has been done is to structure the waste classification in such a way that both heterogeneous and homogenous wastes can be classified with equal ease and clarity.

Classification of waste disposal routes

As described earlier, the MEFA recognises two routes for the disposal of wastes. One is direct release to the environment through the air, water or land. The other is disposal in some form of controlled or contained site. These two routes represent the major headings of the waste disposal route classification shown in Text Box 4.4. Each of the major disposal routes is further subdivided into more specific routes through which wastes can be disposed.

Text Box 4.3
Waste Classification

1 Organic compounds and materials
- 1.1 Petrochemicals and feedstocks
- 1.2 Pesticides
- 1.3 Halogenated compounds (other than pesticides)
  - 1.3.1 Dioxans and furans
  - 1.3.2 Chlorofluorocarbons
  - 1.3.3 Others
- 1.4 Plastic
- 1.5 Rubber
- 1.6 Grease and oil
- 1.7 Bio-source material
  - 1.7.1 Wood and wood by-products
  - 1.7.2 Other plant material
  - 1.7.3 Paper
  - 1.7.4 Animal-based material
  - 1.7.5 Sewage
- 1.8 Organic mixtures and composites nec

2 Inorganic compounds and materials
- 2.1 Halogens and their compounds
  - 2.1.1 Chlorine-based
  - 2.1.2 Others
- 2.2 Ferrous metals and their compounds
- 2.3 Non-ferrous metals and their compounds
  - 2.3.1 Non-radioactive
  - 2.3.2 Radioactive
- 2.4 Oxides of carbon, nitrogen and sulphur
- 2.5 Mineral acids
- 2.6 Nitrates, phosphates and sulphates
- 2.7 Synthetic fertilisers
- 2.8 Minerals and mineral-based materials
  - 2.8.1 Asbestos
  - 2.8.2 Glass
  - 2.8.3 Others
- 2.9 Particulate matter
- 2.10 Soil
- 2.11 Inorganic mixtures and composites n.e.s

3 Durable goods
- 3.1 Transportation equipment
- 3.2 Machinery and appliances
- 3.3 Furnishings
- 3.4 Mixed demolition waste
- 3.5 Other durable-good wastes

4 Waste energy
- 4.1 Heat
- 4.2 Light
- 4.3 Noise

1. A **mixture** can be defined as a heterogeneous combination of substances in any physical state (solid, liquid, gas) in which the components are dispersed (uniformly or non-uniformly) at the micro level. Examples include paint, glass and exhaust gases. A **composite** can be defined as a heterogeneous combination at the macro scale of two or more solid materials that are mutually insoluble and differ in chemical nature. Examples are laminates, reinforced plastics, fabrics and asphalt.

Text Box 4.4
Classification of Waste Disposal Routes

1 Environment
- 1.1 Air
  - 1.1.1 Over urban areas
  - 1.1.2 Over rural areas
- 1.2 Land
  - 1.2.1 Urban areas
  - 1.2.2 Agricultural land
  - 1.2.3 Forest land
  - 1.2.4 Underground
  - 1.2.5 Other land
- 1.3 Water
  - 1.3.1 Lakes
  - 1.3.2 Rivers
  - 1.3.3 Oceans
  - 1.3.4 Groundwater

2 Disposal sites
- 2.1 Landfill sites
  - 2.1.1 Sanitary
  - 2.1.2 Non-sanitary
- 2.2 Mine tailings piles
- 2.3 Waste storehouses
  - 2.3.1 For nuclear wastes
  - 2.3.2 For other wastes

The environment is divided broadly into air, land and water, each of which is again further subdivided into several more specific categories. Although each of these specific categories could in turn be further divided, this is currently unnecessary. The waste statistics that are available for incorporation into the MEFA do not lend themselves to being classified more finely than is possible with the simple classification in Text Box 4.4. If necessary, the classification will be further expanded to allow for more detailed statistics to be recorded in the future.

The classification of managed disposal sites (Category 2 in Text Box 4.4) is also relatively simple, being restricted to only the most important of such sites. Sanitary landfill sites (Category 2.1.1) are defined as those facilities run expressly for the purpose of disposing of municipal solid waste in which some form of physical barrier is used to isolate the waste from the immediate environment. Non-sanitary land fill sites (Category 2.1.2) are defined as disposal sites for solid wastes in which no special effort is made at isolating the wastes from the immediate environment. This includes public garbage dumps in which wastes are simply tipped into open pits or piles, as well as dumps used for the on-site disposal of wastes at industrial facilities. Mine tailings piles (Category 2.2) are used for the disposal of waste rock and other debris at mine sites. Finally, waste storehouses (Category 2.3) are defined as managed facilities in which wastes (normally hazardous in some way) are placed for long-term storage. The best example is the holding pools in which spent nuclear fuel rods are currently stored.

Classification of waste sources not related to current economic activity

Relatively few sources of wastes not related to current economic activity need be recognised in the MEFA. The relevant categories are shown in Text Box 4.5. The headings in this classification have already been discussed above (or are self-explanatory) and do not require further explanation.

Text Box 4.5
Classification of Non-economic Waste Sources

1 Catastrophic spills
- 1.1 On water
- 1.2 On land

2 Leakages from waste disposal sites
- 2.1 Landfill sites
- 2.2 Toxic waste storehouses

At this point, the full conceptual details of the MEFA have been presented and discussed. The remainder of the chapter is devoted to discussing the data sources and methods used to date in the development of the accounts.

4.4 Data sources and methods

Many sources of data describing resource and waste flows exist in Canada. These include government sources such as published and unpublished inventories from monitoring programs, one-time research studies, and administrative data. Universities, private consulting firms, corporate environmental reports, and environmental organisations are also useful sources.

Generally speaking, data from these sources share one or more of the following characteristics.

- The data represent only a subset of the resource or waste flows relevant to a particular issue. This might mean that they do not cover all sectors of the economy, that they represent only certain regions of the country, that they focus only on specific categories of resources or wastes, or any combination of the above.
- The data are not published, or are published only irregularly. This might be because they result from a one-time research study, or it could be that they come from an environmental monitoring program that has ceased to exist.
- Data from different sources and/or time periods are often incompatible with one another. Different classifications and inconsistent collection methods can render data sets incompatible for example.

- Finally, the data lack any integration with economic statistics.

The above list is not meant as a criticism of the resource and waste flow data currently available. Indeed it would be surprising if data sets from different organisations were compatible, as each agency has a different need to fulfill when it sets out to collect data. Rather, the list simply outlines the difficulties that data users can face when trying to compile and use waste data from different sources. The MEFA go some way toward solving these difficulties by incorporating data from various sources into a consistent and comprehensive accounting framework and making them available through a single source.

To date, the empirical development of the MEFA has been focused in the following areas:

- water;
- energy; and
- greenhouse gases.

The data sources and methods used to estimates flows of these resources and wastes in MEFA are described in this section.

4.4.1 Water

The MEFA present detailed water flow data for industries, households and governments. Currently, these data cover the years 1981, 1986 and 1991. Text Box 4.6 shows the water-use parameters that are measured in the MEFA.

Due to the efforts of Environment Canada over the past two decades, excellent time series of industrial and municipal water-use data exist in Canada. The industrial data are collected through a series of joint Environment Canada/Statistics Canada surveys of industrial water use (see for the most recent example, Tate and Scharf, 1995). The municipal water-use data are collected by Environment Canada through the *Municipal Water Use Database* (Environment Canada, 1994). These two surveys are the principal sources of water-use data for the MEFA. Water use for consumers not covered by either of these surveys is estimated using other methods.

Text Box 4.6
Water Use Parameters

The following list defines the most important water-use parameters included in the MEFA.

- **Water intake** is defined as water withdrawn from the ground or surface for use in economic activity. Intake can either be self-supplied (that is, withdrawn from source directly by the user), or publicly supplied (withdrawn by public water utilities and delivered to end users).
- **Recirculation** refers to the use of a given volume of water at least twice by an industrial establishment. Recirculation does not refer to water reused within a particular process of a plant, but only to water that leaves a process and re-enters it again or is used in another process.
- **Gross water use** is defined as the sum of water intake plus recirculation.
- **Consumption** is that part of water intake that is evaporated, incorporated into products or crops, consumed by humans or livestock, or otherwise removed from the local hydrologic environment.
- **Discharge** is water returned to a surface- or groundwater source, either directly or through a municipal sewer system, after release from the point of use.

Data sources and methods

Except for the agriculture industry, estimates of water use for major water-using industries are derived from Environment Canada's industrial water use surveys. These surveys cover the mining industries, the manufacturing industries and the thermal electric power industry. Approximately 85 percent of total industrial water use is accounted for by the surveyed industries.

Agriculture industry - Agricultural water-use estimates are prepared by Environment Canada by combining data for livestock numbers and land-area under irrigation with water-use coefficients.

Mining industries - Water use in metal mines, non-metal mines, coal mines and (except for 1991) crude petroleum and natural gas plants are covered by the *Survey of Water Use in Mineral Extraction Industries*. This survey covers all significant operating establishments within these industries and, therefore, few adjustments to the survey data are required before they are incorporated into the MEFA. The major adjustment is to modify the treatment of water that must be pumped from mines to prevent flooding (known as minewater). Minewater is not considered water intake by the mining industries in the survey, although it is considered as part of their discharge. The result is that the survey reports water discharge as exceeding water intake for these industries. Rather than adopt this treatment in the MEFA, minewater is instead included in intake, on the grounds that it represents an unavoidable diversion of water in association with mining activity. The fact that minewater is not intentionally diverted does not diminish this fact. Water intake is therefore equal to water discharge for the mining industries in the MEFA.

Estimates of water use are made for the mining industries not covered by the survey (quarries and sand pits, and mining services). The estimates for quarries and sand pits are based on a per-employee U.S. coefficient (U.S. Bureau of the Census, 1981) applied to Statistics Canada employment data for this industry. No suitable data exist to employ in estimating water use by the mining services industry (which comprises mainly contract drilling companies); these estimates are based on professional judgement.

Manufacturing industries - Approximately one half of all manufacturing industries are covered by the *Survey of Water Use in Manufacturing Industries.* The share of manufacturing water use captured by this survey is closer to 85 percent however, as the surveyed industries include all of the large water-using establishments in the manufacturing industries. Data for these industries are incorporated directly into the MEFA with only minor adjustments. The most important is a slight upward adjustment to account for the small establishments within each industry that are not covered by the survey. The ratio of water use to employment for the surveyed establishments, taken on an industry-by-industry basis, is applied to each non-surveyed establishment to make this adjustment. Adjustments are also required to correct for obvious reporting errors and/or non-response.[1] These adjustments are again made by applying the ratio of water use to employment for the surveyed establishments to each establishment for which there was no response or an obviously incorrect response.

For those manufacturing industries not covered by the survey, an estimate of water use is derived by combining employment data[2] with per-employee water-use coefficients. For many of these industries, a water-use coefficient based on U.S. data is available (U.S. Bureau of the Census, 1986). For industries for which no appropriate U.S. coefficient is available, a per-employee coefficient based on employment and water use in the most similar Canadian industry that is included in the manufacturing water use survey is used.

Thermal electric power industry - Water use estimates for thermal electric power stations are available from the *Survey of Water Use in Thermal Power Plants*. All operating power plants are included in this survey, so there is no requirement for adjustment of the survey data before incorporation in the MEFA.[3]

A small number of establishments other than electric power stations also produce thermal electric power (mainly for self-consumption, but occasionally for sale as well). The water used by these small producers is collected along with that used at thermal electric power stations through the thermal power plant survey. This water use is transferred to the industries in which the production occurs before the data are incorporated into the MEFA.

Other industries - For the remaining, non-surveyed industries (construction, transportation, finance, retail and wholesale trade and other services) one of two methods is employed in estimating water use. For industries involved in the areas of accommodations and entertainment, a combination of Statistics Canada data on customers served and per-customer water-use coefficients is used. For other industries, Statistics Canada employment data are combined with per-employee water-use coefficients. Several different sources of per-customer and per-employee coefficients are used in making these estimates: the U.S Army Corps of Engineers (Davis *et al.*, 1988); water audits conducted by Environment Canada, Public Works and Government Services Canada and various municipal engineering departments; and engineering consulting reports.

Several assumptions are made in estimating water use for the non-surveyed industries. First, it is assumed that all of them (except construction[4]) derive all their water from municipal sources. Second, it is assumed that they all discharge their water into municipal sewer systems (again with the exception of construction). Finally, these industries are all assumed to consume at least some water for drinking, food preparation, lawn watering, vehicle cleaning and other purposes. The percentage of their intake consumed is estimated using a combination of professional judgement and data from the U.S. Geological Survey (Solley *et al.*, 1993). The estimates of consumption vary between 5 percent and 30 percent of total intake, depending upon the nature of the industry. Industries engaged in activities in which water is used for many consumptive purposes (accommodation and food services for example) are placed at the high end of this range; those whose activities do not result in much consumptive water use (financial services for example) are placed at the low end of the range. The remaining industries are placed in the middle.

Households - Water use by households served by municipal water supply systems is available from Environment Canada's *Municipal Water Use Database* (MUD). Only one modification is made to the MUD data before they are incorporated into the MEFA. This is the reallocation of water use in apartment buildings from the business sector, where it is classified in the MUD data, to households.

MUD does not contain estimates of water use by persons not served by municipal water supply systems; that is, for those who supply their own water from underground wells or by pumping directly from surface water. Estimates are made for this portion of the population by multiplying the number of persons not served by municipal systems[5] by a per-capita water-use coefficient for self-supplied households (Carr *et al.*, 1990).

Governments - A combination of employment data or–in the case of government services–persons served,[6] with

1. Reporting errors and non-response may be due to the tendency in major industries toward self-supply of water. Because of the low cost associated with self-supplied water, some establishments may feel that water use does not warrant detailed record keeping.
2. Employment data are taken from the *Survey of Manufactures*.
3. Following the treatment in Environment Canada's water-use surveys, instream water use for hydroelectric power generation is not measured in the MEFA.
4. The construction industries are assumed to supply some of their own water from surface sources. Amounts are estimated based on professional judgement.
5. The number of persons served by municipal water systems is available from MUD. The number of persons not served is estimated as the difference between this number and the total population.
6. Data on persons served are used to estimate water use in the following government service areas: schools, hospitals and other care facilities, correctional institutions and airports and train stations.

per-employee (or per-person) water-use coefficients are used to estimate water use for the government sector. The same assumptions about water intake, discharge and consumption just mentioned with respect to industries apply as well to governments. Again, consumption shares range from 5 percent to 30 percent of total intake.

Data accuracy

The MEFA water data are considered to be very accurate in the case of consumers for which estimates are based on survey data. This includes the mining, manufacturing and electric power industries, plus households and governments. Because these groups represent the largest water consumers in the economy, the overall accuracy of the water use data is considered to be very good. The estimates for consumers for which no direct survey data are available are considered to be of lower, but still acceptable, accuracy. These estimates are mainly based on a combination of coefficients drawn from reliable U.S. or Canadian sources with Statistics Canada economic or demographic statistics.

4.4.2 Energy

The MEFA record in quantitative units (joules) the annual consumption of energy commodities by industries, persons and governments.[1] The current period of coverage is 1981-1992 inclusive.

Eleven energy commodities are represented in the accounts: coal, crude oil, natural gas, liquid petroleum gases, electricity, coke, motor gasoline, diesel fuel, aviation fuel, light fuel oil and heavy fuel oil. Both the consumption of these commodities for their energy content (the combustion of gasoline in motor vehicles for example) and as material feedstocks (natural gas used as a raw material in fertiliser production for example) are measured in the accounts.

The 11 energy commodities represented in the MEFA match exactly with those represented in the Input-Output Accounts. As explained below, the Input-Output Accounts are an important source of energy data for the MEFA; it is for this reason that the two share identical classifications of energy commodities. These commodities subsume all 24 of the energy commodities for which economy-wide production and consumption data are published by Statistics Canada in the *Quarterly Report on Energy Supply-Demand in Canada* (QRESD).[2] Regular users of Statistics Canada energy data will be familiar with the latter publication and may wonder what differentiates the MEFA energy data from the QRESD. A direct comparison shows that the two in fact complement one another.

Text Box 4.7

Comparison of Energy Commodities in the MEFA the QRESD

MEFA	QRESD
Coal	Canadian bituminous coal U.S. bituminous coal sub-bituminous coal anthracite coal lignite coal
crude oil	crude oil
natural gas	natural gas
motor gasoline	motor gasoline
aviation fuel	aviation turbo fuel aviation gasoline
diesel fuel	diesel fuel
light fuel oil	light fuel oil kerosene
heavy fuel oil	heavy fuel oil
liquified petroleum gases	propane butane ethane refinery still gas coke oven gas
electricity	primary electricity (hydro and nuclear) secondary electricity (fossil thermal)
coke	petroleum coke coal coke

The first important difference between the two can be seen in Text Box 4.7, which compares the energy commodities of the MEFA to the more detailed QRESD commodities. From this table, it is immediately obvious that there is considerably less detail with respect to certain energy commodities in the MEFA. Coal, for example, is represented in terms of five different coal types in the QRESD, while the MEFA represents coal as a single commodity. Most of the important energy commodities (in terms of the percentage of total energy they supply) are represented with as much detail in the MEFA as in the QRESD however.

The second important difference between the MEFA and QRESD relates to their frequency and timeliness of publication. The QRESD, as its name implies, is published each quarter and is released a few months following the reference period. The MEFA, in contrast, are annual and are (currently) available only four years after the reference year.

What the MEFA lack in energy commodity detail and timeliness, they make up for in terms of industrial detail. Whereas the QRESD breaks the economy into 19 industry groupings, plus households and governments, the MEFA in their most detailed form provide energy data for 161 industries, households and governments. Moreover, being structured according to the accounting framework presented earlier in Figure 4.1, the energy data in the MEFA may be easily com-

1. The energy flows included in the MEFA to date focus on energy consumption only. Detailed energy production statistics are available from several other Statistics Canada sources and, since production tends to be concentrated in a few industries, the industrial detail offered by the MEFA is not as important with respect to energy production as it is with respect to energy consumption. Energy production statistics will be incorporated into the MEFA in the future.
2. Statistics Canada, Catalogue no. 57-003.

Text Box 4.8
Energy Data Sources for the MEFA

Data requirement	Data Source	Comment
Value of energy purchases for all businesses, households and governments	Input-Output Accounts (constant dollar version)	
Mining industries, energy consumption in physical units	*Census of Mines, Quarries and Sandpits*	Due to unavailability of data from the *Annual Survey of Manufactures*, physical data for all industries during period 1987-1989 inclusive are taken from the *Quarterly Report on Energy-Supply Demand in Canada* (Catalogue no. 57-003).
Manufacturing industries - energy consumption in physical units	*Annual Survey of Manufactures*	Due to unavailability of data from the *Annual Survey of Manufactures*, physical data for all industries during period 1987-1989 inclusive are taken from the *Quarterly Report on Energy-Supply Demand in Canada* (Catalogue no. 57-003).
For-hire transportation industries - energy consumption in physical units	*Air Carrier Operations in Canada* (Catalogue no. 51-002) *Railway Transport in Canada* (Catalogue no. 52-215) *Rail in Canada* (Catalogue no. 52-216) *Trucking in Canada* (Catalogue no. 53-222) *Shipping in Canada* (Catalogue no. 54-205) *Passenger Bus and Urban Transit Statistics* (Catalogue no. 53-215)	Up to and including 1986, the data source for the rail transport industry was *Railway Transport in Canada*. This catalogue was discontinued in 1986. Subsequent to 1986, *Rail in Canada*, first issued in 1987, became the data for this industry.
Electric power industry - energy consumption in physical units	*Quarterly Report on Energy Supply-Demand in Canada* (Catalogue No. 57-003)	
Total energy consumption in physical units	*Quarterly Report on Energy Supply-Demand in Canada* (Catalogue No. 57-003)	
Producer consumption of energy commodities in physical units	*Quarterly Report on Energy Supply-Demand in Canada* (Catalogue No. 57-003)	
Non-energy consumption of energy commodities in physical units	*Quarterly Report on Energy Supply-Demand in Canada* (Catalogue No. 57-003)	
Consumption of fuel of own-production in physical units	*Quarterly Report on Energy Supply-Demand in Canada* (Catalogue No. 57-003)	

bined with economic data from the Input-Output Accounts. This allows very detailed analysis of the relationship between energy use and economic activity.

Thus, rather than being substitutes for one another, these two sources of energy data are in fact complementary. Those users requiring very timely and frequent energy data can turn to the QRESD. There is a cost for these “up-to-the-minute” data in terms of reduced industrial detail. Other users who are more interested in industrial detail and analytical power may find their needs better met by the MEFA.

Data sources

The energy flows recorded in the MEFA are estimated using data from a variety of Statistics Canada sources. Each of these sources, along with the data requirements it serves, is outlined in Text Box 4.8.

Two of the sources listed in Text Box 4.8, the *Census of Mines, Quarries and Sandpits* and the *Annual Survey of Manufactures*, provide the majority of the energy consumption data required for the MEFA. These two surveys collect–among many other statistics–quantitative data on the annual use of energy commodities by mining and manufacturing establishments. The use of energy commodities as both energy sources and as material inputs is collected. Aggregated by commodity and industry, these data are a key input into the MEFA.

The QRESD is also a very important source of energy data. It provides benchmark estimates of total annual availability[1] for each energy commodity. Total consumption of each of the 11 energy commodities represented in the MEFA must be equal to the reported QRESD availability. The QRESD is also the source of data on the quantities of energy commodities consumed directly by their producers (for example, the

1. Availability is defined for each commodity as domestic production plus imports less exports with adjustments made for inventory changes and interproduct and inter-regional transfers. See Catalogue no. 57-003 (QRESD) for a more detailed description.

consumption of natural gas in natural gas processing plants). Lastly, the QRESD provides estimates of the quantity of fossil fuels consumed by the electric power industry.

The above three sources provide quantitative data for the most important energy-consuming industries. These industries combine to represent more than 50 percent of total consumption for each of the energy commodities represented in the accounts. For some commodities, coal and crude oil in particular, these industries represent upwards of 100 percent of economy-wide consumption.

The remainder of the energy data required for the MEFA, including those for households and governments, come from the Input-Output Accounts (with the exception of the for-hire transportation industries, for which data are available from the Statistics Canada sources listed in Text Box 4.8). Incorporation of the data from the Input-Output Accounts, which it should be recalled are measured in dollar values and not physical quantities, follows the method described in the following section.

Although every effort is made to employ consistent data sources when compiling the MEFA, discontinuities in Statistics Canada data collections occasionally prevent this ideal from being reached. Such is the case for energy data. Changes to the *Annual Survey of Manufactures* during the period 1987-1989 reduced the quality of the quantitative energy consumption data collected during those years below the level acceptable for use in the MEFA. In the absence of these data, the QRESD serves as the source for all energy data in the MEFA during the period 1987-1989.

Method

As described above, reliable, quantitative estimates of annual energy use are available for the major energy-using industries directly from Statistics Canada surveys. Little more is required to incorporate these data into the MEFA than to aggregate them according to the MEFA classifications of industries and energy commodities.[1] In the case of energy consumers for which suitable quantitative data are not directly available, an alternative estimation method based on the Input-Output Accounts is used.

The use of the Input-Output Accounts first requires that the available quantitative data be summed for each energy commodity. These amounts are then subtracted from total availability by commodity (from the QRESD), leaving a residual quantity of unallocated availability for each commodity. These residual quantities represent consumption by those consumers for which no direct quantitative data are available. The equivalent value of their energy consumption is calculated from the Input-Output Accounts by summing their energy purchases on a commodity-by-commodity basis. Dividing the value of purchases so calculated by the residual availability for each commodity yields an implicit unit price paid for energy by these consumers. This unit price, in turn, is used to estimate the quantity of energy consumed by each of these consumers by dividing their purchases by the unit price.

An example of the method used to compile the energy consumption data for the MEFA is presented in Table 4.1. Total availability of 100 units of a given energy commodity is allocated across a simplified economy consisting of three industries plus households and governments.

Table 4.1
Allocation of an Energy Commodity

Sector	Quantity consumed (units)	Value of purchases	Quantity entered in MEFA energy use account (units)
Mining industries	10	n/a	10
Manufacturing	50	n/a	50
Other industries	n/a	75	(75/200) x (100-60) = 15
Households	n/a	75	(75/200) x (100-60) = 15
Governments	n/a	50	(50/200) x (100-60) = 10
Total	**60**	**200**	**100**

Data accuracy

The accuracy of the MEFA energy consumption data is, in general, good. As mentioned above, the major portion of the consumption of each energy commodity is derived from quantitative data based on well-established Statistics Canada surveys in which energy suppliers (or consumers) are asked to report the quantities of energy commodities they have sold (or purchased) in the previous year. Furthermore, the consumers from whom quantitative data are collected are typically those that use large quantities of energy. These are the same consumers who are most likely to accurately monitor and record their energy consumption.

This said, it must be acknowledged that the method used to estimate energy consumption for those consumers for whom no quantitative data are available produces results that are of lower accuracy. Implicit in this method is the assumption that the price paid for a given energy commodity is exactly the same for all consumers included in the allocation of residual availability. In reality this is not the case. Consumers across the country pay different prices for the same energy commodity depending upon a number of factors: their proximity to energy suppliers, the volume of their purchases, the grade of fuel that they purchase, and the supplier from whom they buy. To the extent that these factors cause the price paid for a given commodity by a given consumer to deviate from the implicit unit price used in the residual allocation, the quantity of energy assigned to that consumer in the MEFA is inaccurate. It is worth bearing in mind that the consumers included in the allocation of residual availability are (with the exception of households) not large energy consumers and that the overall accuracy of the energy data is therefore not seriously degraded by this assumption.

1. Minor adjustments are made to the data to account for small establishments not covered by the surveys.

4.4.3 Greenhouse gases

Given the attention focused on the issue of climate change in the early 1990s, data on greenhouse gas emissions (carbon dioxide, methane and nitrous oxide) were among the first incorporated into the MEFA.[1] The current period of coverage for these flows is 1981-1992 inclusive.

The methods used for estimating annual emissions of these gases are based on a 1990 inventory of greenhouse gas emissions developed by Environment Canada (Jaques, 1992). Except where otherwise noted, this study is used as the basis for the estimation of all greenhouse gas emissions data included in the MEFA.

Carbon dioxide emissions

Emissions of carbon dioxide (CO_2) are the most straightforward of the greenhouse gases to measure. Emissions of this gas are primarily related to the combustion of fossil fuels (more than 90 percent of Canadian emissions result from this activity). Moreover, unlike other greenhouse gases, the quantity of CO_2 produced per unit of fuel burned does not vary significantly with the conditions of combustion; in nearly all processes where fossil fuels are burned, essentially all of the carbon found in the fuel is ultimately converted to CO_2. Thus, it is possible to calculate a single set of emission factors that accurately express the quantity of carbon dioxide produced per unit of fossil fuel burned (in tonnes of CO_2 per terajoule of fuel). Text Box 4.9 shows such a set of emission factors developed by Environment Canada. These factors are combined with MEFA energy data to estimate carbon dioxide emissions from fossil fuel combustion for the MEFA.

There are also non-combustion uses of fossil fuels that result in the release of CO_2. These are related to the use of fuels as feedstocks in certain industries. The emissions factors developed by Environment Canada for these sources are combined with MEFA data on feedstock energy commodity use to estimate the associated carbon dioxide emissions.

Text Box 4.9
Carbon Dioxide Emission Factors for Fossil Fuel Combustion

Fuel type	Carbon dioxide emission factor (tonnes/terajoule)
Natural gas	49.68
Still gas	49.68
Automobile gasoline	67.98
Kerosene	67.65
Aviation gasoline	69.37
Liquified petroleum gases	59.84 - 61.38
Diesel oil	70.69
Light fuel oil	73.11
Heavy fuel oil	74.00
Aviation turbo fuel	70.84
Petroleum coke	100.10
Coal coke	86.00
Anthracite coal	86.20
U.S. bituminous coal	81.60 - 85.90
Canadian bituminous coal	83.00 - 94.30
Sub-bituminous coal	94.30
Lignite coal	93.80 - 95.00

Note:
In cases where the emission factor is expressed as a range, the mid-point of the range is used in estimating carbon dioxide emissions in the MEFA.
Source:
Jaques, 1992, p. *xx*.

Aside from fossil fuel-related sources, several industrial processes produce significant quantities of CO_2: cement and lime production, ammonia production and natural gas production. The CO_2 emissions associated with each of these non fuel-combustion sources are again estimated using emission factors developed by Environment Canada. These factors are combined with Statistics Canada data on cement, lime, ammonia and natural gas production[2] to estimate the associated CO_2 emissions.

Note that CO_2 emissions from the combustion of biomass (wood waste and fuel wood) are not recorded in the MEFA. These are assumed to be off-set by the natural uptake of carbon dioxide due to forest growth and, therefore, not to make a net contribution to Canadian emissions.

1. The so-called “greenhouse effect” is a natural phenomenon whereby certain trace atmospheric gases absorb a portion of the heat radiating from the planet’s surface, trapping and reflecting it back before it escapes to space. In this way the gases act like the covering on a greenhouse (hence the name given to the effect). By preventing this heat from escaping to space, these “greenhouse gases” keep global temperatures much warmer than would be the case in their absence. Indeed, in the absence of the greenhouse effect, the planet would be too cold to support life. In recent years scientists have expressed concern that human-induced changes in the atmospheric concentrations of certain greenhouse gases are significantly enhancing the naturally occurring greenhouse effect (Houghton *et al.*, 1996). This enhancement is predicted to cause warming of the earth’s atmosphere and significant disruptions in global climatic systems. The principal gases responsible for the enhancement in the greenhouse effect are carbon dioxide, methane, nitrous oxide, and the group of compounds known as halocarbons. (Halocarbon is the generic term for any carbon-based compound that contains chlorine, fluorine, bromine or iodine. The best known of this group are the so-called chlorofluorocarbons. Widely recognised for their role in depletion of the ozone layer, these compounds are also potent greenhouse gases.)

2. Statistics Canada, Industry Division.

Methane emissions

According to Environment Canada, methane emissions are associated with the following economic activities:

- rearing of farm animals;
- coal mining;
- oil and gas production and distribution;
- solid waste disposal;
- stationary and transportation fossil fuel combustion; and
- controlled burning of logging residue.

Estimates of the emissions of methane from all of these sources are included in the MEFA, again based on the estimation methods developed by Environment Canada.

Agricultural methane emissions are associated with livestock rearing. The anaerobic digestion of forage in the rumen (first stomach) of certain farm animals results in substantial releases of methane, as does animal manure. The emissions associated with digestion are approximately twice those associated with manure. Cattle are the most significant source of digestive releases, with a mature dairy cow estimated to produce 120 kg of methane annually. Environment Canada reports that Canadian cattle of all types produced 612 kilotonnes of methane from their digestive processes in 1990, or about 16 percent of total methane emissions associated with economic activity.

Combining the per-head emission factors developed by Environment Canada for various species of farm animals with Statistics Canada livestock population data,[1] estimates of digestive methane releases are developed for the MEFA. Methane releases from animal manure are similarly estimated using the per-head manure production rates and methane conversion factors developed by Environment Canada. Total livestock methane emissions–from digestion and manure–are classified to the Livestock Agriculture Industry in the MEFA.

Coal mines can be significant sources of methane emissions, depending upon the type of coal mined and location of the mine site (surface or underground). The amount of methane trapped in coal seams varies significantly from location to location. Generally speaking, deep underground mines tend to release more methane than surface mines, as much of the methane trapped in surface coal deposits has escaped over geologic history.

Environment Canada has estimated total methane emissions associated with coal mining activity in 1990. This estimate is prorated using Statistics Canada data on coal production by mine type (surface or underground)[2] to produce estimates for inclusion in the MEFA.

Natural gas production and distribution - Natural gas is essentially pure methane. Thus, any releases of natural gas to the atmosphere during its extraction and distribution are recorded in the MEFA as methane emissions. Environment Canada has estimated natural gas releases from the production and distribution of gas for the year 1990. This figure is prorated using Statistics Canada data on gas production[3] to estimate methane emissions from these activities for inclusion in the MEFA. The emissions associated with natural gas production are classified to the Crude Petroleum and Natural Gas Extraction Industry, while those associated with gas distribution are classified to the Gas Distribution Systems Industry.

Landfill sites are major sources of methane emissions. Under the appropriate moisture, acidity, temperature and nutrient conditions, methanogenic bacteria present in the waste pile decompose the organic matter and produce methane gas as a by-product. Typically, this methane simply escapes to the atmosphere by seeping through the buried waste. Although some landfill sites are equipped with systems to trap and burn the methane. Environment Canada has estimated that approximately 1.6 megatons of methane was produced in landfill sites in 1990. Of this, approximately 13 percent was captured and burned, leaving just over 1.4 kilotonnes to escape to the atmosphere. This figure is included in the MEFA for 1990 in the matrix of wastes not related to current economic activity (matrix *S*). Estimates of landfill methane emissions for other years have not yet been made.

Fuel combustion methane emissions are small in comparison with those from the sources mentioned above. Environment Canada reports that less than one percent of the methane emissions associated with economic activities result from this activity. Methane is produced both by stationary combustion equipment and by motor vehicles, with approximately three quarters of total fuel combustion emissions originating from the latter source.

Environment Canada has published a set of methane emission factors for various fuels and stationary combustion equipment (utility boilers, industrial boilers, commercial boilers and residential boilers/heaters). These emission factors (expressed in kilograms CH_4 per terajoule of fuel burned) are combined with MEFA fossil fuel consumption data to estimate stationary fuel combustion methane emissions. Assumptions are made about the kind of heating equipment likely to be used by each fuel consumer: manufacturing industries are assumed to use industrial boilers; electric power plants are assumed to use utility boilers; all other industries plus governments are assumed to use commercial boilers; households are assumed to use residential boilers/heaters.[4]

1. Statistics Canada, Agriculture Division.
2. Statistics Canada, *Coal Mines*, Catalogue no. 26-206.
3. Statistics Canada, *Energy Statistics Handbook*, Catalogue no. 57-601.
4. Methane is also produced during the combustion of fuel wood and wood waste combustion. These emissions are, however, extremely small. Environment Canada estimates that these sources contributed less than one tenth of one percent of all methane emissions from economic activity in 1990. This value is insignificant in comparison to the uncertainty in the estimates of methane emissions from other sources and, therefore, is excluded from the MEFA.

Methane emissions from transportation fuel use are also based on emission factors available from Environment Canada. Emission factors (expressed in kilograms CH_4 per terajoule of fuel burned) for rail, marine, air and off-road land transportation are combined with MEFA fuel use data to estimate methane emissions from these activities.

Estimates of methane emissions from on-road transportation are taken from the results of a computer simulation model known as *Mobile 5C* (Kirshenblatt, personal communication). This model has been adapted by Environment Canada from the *Mobile 5* model originally developed by the U.S. Environmental Protection Agency. The U.S. The model produces national and provincial inventories of total hydrocarbon (THC), non-methane hydrocarbon (NMHC), nitrogen oxide (NO_x) and carbon monoxide (CO) emissions from various categories of road motor vehicles.[1] Methane emissions are calculated as a percentage of the difference between THC and NMHC emissions.

The incorporation of data from MOBILE 5 into the MEFA is not straightforward. The challenge comes in allocating the emissions from each vehicle category among industries, households and governments. The available Statistics Canada data on motor vehicle registrations[2] are inadequate for this task, since they indicate only how many vehicles are registered in the country and not by whom they have been registered. In the absence of appropriate registration data, a less refined approach to allocating the emissions from MOBILE 5C is used. First, professional judgement is used to decide who, among industries, persons and governments, is likely to use which type of road vehicles. Once the “users” of each vehicle type are determined, the associated emissions from the MOBILE 5C national inventory are distributed among the users in proportion to their consumption of motor fuels. For example, in the case of light duty gasoline vehicles, it is judged that persons, governments, taxi cabs, auto manufacturers and the “travel and entertainment” industry are the predominant users of this type of vehicle. The associated methane emissions are distributed among these users in proportion to each user’s share of the gasoline consumption of the group as a whole.

Prescribed fires for the purposes of forest management are the final source of methane emissions included in the MEFA. Environment Canada estimates that about 38 kilotonnes of methane (1 percent of emissions from economic activities) were released from such fires in 1990. Their estimate is based on a 10-year average of area burned in prescribed fires during the 1980s. Thus, the figure of 38 kilotonnes is assumed to be valid for each year during the 1980s. It is classified to the Logging and Forestry Industry in the MEFA.

1. Light duty gasoline vehicles, light duty diesel vehicles, light duty gasoline trucks, heavy duty gasoline trucks, heavy duty diesel trucks and motorcycles.
2. Statistics Canada, *Road Motor Vehicles - Registrations*, Catalogue no. 53-219.

Nitrous oxide emissions

Environment Canada reports that nitrous oxide emissions are associated with the following economic activities:

- production of adipic acid;[3]
- fossil fuel use for transportation;
- use of nitrogen fertilizers;
- stationary fuel combustion (including fuel wood and wood waste);
- production of nitric acid;
- use of anaesthetics;[4] and
- use of propellants in consumer goods.[5]

Of these sources, the most important are adipic acid production (33 percent of 1990 emissions), transportation (32 percent), fertilizer use (12 percent) and stationary fuel combustion (12 percent). The remaining 12 percent of 1990 emissions were the result of the other sources listed above. Estimates of the emissions of nitrous oxide from all of these sources are included in the MEFA based on methods developed by Environment Canada.

Environment Canada reports that nitrous oxide is produced as a by-product during the production of both **nitric acid** and **adipic acid**. The former is used for many purposes (fertilizer production, organic chemical production, photoengraving, and etching steel among many others), while the latter is used almost exclusively in the production of nylon. The nitrous oxide emissions from nitric acid production are quite small in comparison with those from adipic acid production (approximately one percent of 1990 emissions reported by Environment Canada were due to the former, while 33 percent were due to the latter). A suitable means of adopting the method used by Environment Canada to estimate the emissions associated with nitric acid production has not yet been developed and, therefore, this relatively small source is not currently included in the MEFA. The emissions associated with adipic acid production are more straightforward to measure however, as Environment Canada has developed an emission factor that expresses nitrous oxide emissions per unit of adipic acid produced. This factor is combined with Statistics Canada data on annual adipic acid production[6] to estimate nitrous oxide emissions for inclusion in the MEFA. The emissions from this activity are classified to the Industrial Organic Chemical Industry.

Transportation fuel use is one of the most important sources of nitrous oxide emissions. Environment Canada reports that vehicles equipped with catalytic converters can produce substantial amounts of this gas under certain circumstances. Environment Canada has developed a meth-

3. Adipic acid is a precursor in certain methods of nylon production.
4. Nitrous oxide–also known as laughing gas–is a commonly used to relax patients before surgery and dental work.
5. Canned whipped cream, for example, is propelled using nitrous oxide.
6. Statistics Canada, Industry Division, *Annual Survey of Manufactures*.

od for estimating nitrous oxide emissions from gasoline powered motor vehicles that combines data on the share of vehicles equipped with various types of catalytic converter[1] with factors expressing nitrous oxide production per unit of gasoline consumption in vehicles equipped with each type of converter. Numbers of gasoline vehicles by type of converter are available from Environment Canada on an annual basis (Mill, personal communication). These are combined with the emission factors developed by Environment Canada and MEFA gasoline consumption to calculate nitrous oxide emissions from gasoline vehicles for industries, households and governments.

Non-gasoline modes of transport (on-road diesel, marine, rail and air) also release nitrous oxide. As the vehicles used in these transportation modes are not usually equipped with catalytic converters, there is no need to factor this element into the estimation of their nitrous oxide emissions. Environment Canada has developed emission factors for various fuels (diesel, heavy fuel oil and aviation fuels) used in transportation activity. These factors are combined with MEFA fossil fuel consumption data to estimate nitrous oxide emissions. All diesel fuel consumption in the economy (except that by electric power producers) is assumed to be used for transportation purposes in this calculation. Only the heavy fuel oil consumed by the rail and marine transport industries is assumed to be for transportation purposes. All aviation fuel is, of course, used for transport.

The use of **nitrogen-based fertilizers** can result in the release of significant amounts of nitrous oxide the necessary soil conditions are present. Environment Canada has estimated that approximately 10.7 kilotonnes of nitrous oxide was evolved from soil to which nitrogen fertilizers had been applied in 1989. The Canadian Fertilizer Institute reports that the nitrogen content of fertilizers sold in 1989 was 1.16 kilotonnes (Brown, J., personal communication). Using these two figures, a crude emission factor can be estimated for the quantity of nitrous oxide evolved per unit of fertilizer nitrogen applied to soil. This factor is applied to annual fertilizer nitrogen sales from the Canadian Fertilizer Institute (ibid.) to estimate nitrous oxide emissions for the MEFA. These emissions are classified to the Fieldcrop Agriculture Industry.

Stationary fuel combustion - Environment Canada has published a set of nitrous oxide emission factors for various fuels. These emission factors (expressed in kilograms CH_4 per terajoule of fuel burned) are combined with MEFA fossil fuel consumption data to estimate stationary fuel combustion nitrous oxide emissions.

The combustion of wood wastes by industry (including prescribed burning for forest management) and the use of fuel wood for heating by households represent reasonably important sources of nitrous oxide emissions. Environment Canada estimates that four percent of total nitrous oxide emissions associated with economic activity in 1990 were due to these sources. Estimates for wood-related nitrous oxide emissions are included in the MEFA based on the single emission factor reported by Environment Canada, which express nitrous oxide emissions in kilograms per tonne of wood burned.[2] Quantities of wood wastes burned for energy purposes by industries are available from Statistics Canada.[3]

Nitrous oxide is commonly used as an **anaesthetic** during surgery and dental work. Based on U.S. data, Environment Canada has developed a per capita emission factor for the releases of nitrous oxide due to anaesthetic use. This factor is combined with Statistics Canada population figures[4] to estimate annual releases for inclusion in the MEFA. Although these emissions are associated with activities in hospitals and dentists offices, no appropriate data exist with which to distribute the emissions between these two sources. Thus, they are directly attributed to households.

The releases of nitrous oxide due to its use as **propellant** in food products have also been estimated by Environment Canada using an emission factor based on consumption patterns in the United States. This factor is combined with Statistics Canada population figures[5] to estimate annual releases for inclusion in the MEFA. Although these emissions are associated with activities in both the business sector and in households, data with which to distribute the emissions between these two sources are not available. Thus, all emissions from this source are directly attributed to households.

Halocarbon emissions

Environment Canada has made estimates of the emissions of halocarbon compounds from various economic sources in 1990.[6] Distributing these emissions across the economy for inclusion in the MEFA is not straightforward. Emissions from refrigeration and air conditioning equipment for example, are attributable to nearly every economic activity because this equipment is so widely used. The same can be said of emissions associated with aerosols and foam rubber. The extent to which each industry, household and government is responsible for the overall emissions of halocarbons from each source is not known at this time.

Aggregate greenhouse gas emissions

As well as measuring emissions of each of greenhouse gas independently, it is also possible to aggregate the emissions and express them as a single value. This is possible

1. Four vehicle types are recognised: no catalytic converter, oxidation catalytic converter, new 3-way catalytic converter and aged 3-way catalytic converter.

2. In the case of prescribed fires, it is assumed that the Environment Canada estimate of 1.2 kilotonnes of nitrous oxide for 1990 holds for the other years in the MEFA. See the discussion of methane emissions from prescribed burning for the reasoning behind this assumption.
3. Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, Catalogue no. 57-003.
4. Statistics Canada, *Quarterly Demographic Statistics*, Catalogue no. 91-002.
5. *Ibid*.
6. Fugitive releases, aerosol propellants, refrigeration and air conditioning, foam rubber and other sources.

Text Box 4.10
Global Warming Potentials[1]

Greenhouse gas	Global warming potential
carbon dioxide	1
methane	21
nitrous oxide	310
hydrofluorocarbons[2]	140 - 11 700
perfluorocarbons[3]	6 500 - 9 200
chlorofluorocarbons[4]	uncertain, probably positive
hydrochlorofluorocarbons[5] and halons[6]	uncertain, probably negative

Notes:
1. Based on a 100-year time horizon.
2. Hydrofluorocarbons are a group of chemicals developed to replace chlorofluorocarbons.
3. Perfluorocarbons are used as refrigerants and solvents.
4. Chlorofluorocarbons are used as refrigerants and solvents. They are perhaps best known by the general public for their role in the depletion of the ozone layer.
5. Hydrochlorofluorocarbons are a group of chemicals developed to replace chlorofluorocarbons.
6. Halons are much used as fire suppresants.

Source:
Houghton *et al.*, 1996.

due to the development of an index known as global warming potential (GWP) (Houghton *et al.*, 1996). GWP measures the heat-trapping potential of each greenhouse gas. Carbon dioxide, the least effective of the gases at trapping heat, is arbitrarily assigned a GWP of one; other gases are assigned values in proportion to their heat-trapping potential relative to that of carbon dioxide. Text Box 4.10 presents GWPs for each of the important greenhouse gases and groups of gases.

GWP is used in the MEFA to weight and aggregate emissions of carbon dioxide, methane and nitrous oxide. Aggregate greenhouse gas emissions for industries, households and governments are expressed in terms of "carbon dioxide equivalent" emissions. It is these aggregate greenhouse gas emission estimates that are used in the derivation of the greenhouse gas intensity indicators discussed in Annex 4.2.

Data accuracy

The estimates of fuel-combustion carbon dioxide emissions are considered to be of good quality. They are based on robust emission factors applied to MEFA energy data that are themselves considered to be good quality. The estimates of carbon dioxide emissions from non-combustion uses of fossil fuels, and from other industrial processes, are less accurate, but are nevertheless considered of fair quality.

The estimates of methane and nitrous oxide emissions are, in general, of low quality. Although based on the best methods available, in many cases the scientific understanding underlying these methods is incomplete. The exception to this rule are the estimates of methane emissions from transportation activities. Based on a refined and detailed transportation model (MOBILE 5C), these estimates are considered to be of fair accuracy. A great deal of effort by the scientific and government communities is currently placed on improving our ability to estimate emissions of greenhouse gases. It is thus reasonable to expect that the quality of these estimates will improve with time.

4.4.4 Data Gaps

Despite the substantial progress made in compiling material and energy flow data for the MEFA, significant gaps remain in the coverage of the accounts, particularly for waste flows. The following areas in which existing data are weak or there is a complete lack of data can be noted.

- Reliable, detailed data on the quantities of non-toxic solid waste (e.g. household solid waste) generated and recycled in Canada do not exist. Those data that do exist are not highly detailed with respect to material composition. More detrimental from the perspective of the MEFA, the data do not classify solid waste flows according to producer. Instead, they generally report just a single measure dubbed "municipal solid waste", which includes all solid waste collected by, or on behalf of, local municipalities and disposed of in local landfill sites. This aggregate comprises part or all of the solid waste generated from households, light industrial and commercial establishments, office buildings, public institutions and government operations. In the absence of information with which to disaggregate these flows according to producer, aggregate solid waste data are not suitable for use in the MEFA.
- Waterborne waste data are weak for all sectors of the economy, particularly for sewage flows. Although some data exist on the quantities and composition of sewage treated in municipal sewage treatment plants, these data suffer from the same problem as the solid waste data described above. That is, the data do not detail the composition of the sewage, and they do not distinguish sewage flows according to producer.
- Data on the production of durable-good wastes are almost entirely lacking. Although the possibility exists to model these waste flows using historical data on purchases of durable goods, this approach is currently unproven.
- Data on leakages from waste inventories are inadequate. Only some rather crude estimates have been made for methane emissions from landfill sites. Estimates of other gaseous emissions and liquid leachates from landfill sites are unavailable.
- Data on public sector waste production are almost entirely lacking. This includes data describing the wastes generated in government office buildings, those associated with the operation of public institutions (hospi-

tals, prisons, military bases, schools) and with the provision of government services (road building and maintenance, for example).

- A general shortcoming in the waste data that are available, even those that are detailed and reliable, is that they do not exist as long time-series. It is rare to find waste data that extend further back in time than the mid 1980s; most begin in the 1990s.
- With respect to resource flows, the major shortcoming is the lack of data representing the flows of recycled materials. Although some data are available on the quantities of municipal solid wastes collected for recycling, again these data do not classify the wastes by producer. Data representing the quantities of waste materials collected for recycling outside of municipal recycling programs are not readily available at all.

4.5 Future directions for the MEFA

Although the MEFA in their current form represent a sound beginning at defining the material and energy flows associated with the Canadian economy, they nevertheless represent only a portion of all the flows that are of interest. Substantial future effort will be aimed at both improving the quality of the estimates currently incorporated in the accounts and at expanding their scope. To this end, work in the next few years will focus in the areas outlined below.

- At a minimum, the material and energy flows currently measured in the accounts will be maintained. This will require annual updating of the series with new data as they become available.
- Beyond merely updating the existing estimates, there are several areas in which efforts will be made at improving the quality of these estimates. The estimates of non-carbon dioxide greenhouse gas emissions and non-survey based water and energy flows can be mentioned as areas deserving of further attention. As well, analysis of the *National Pollutant Release Inventory* is required to determine the extent to which the waste flows it measures are underestimated due to the survey method used by Environment Canada.
- Priorities for the development of new data include emissions of ozone depleting substances, solid wastes, and liquid wastes not covered by the NPRI (primarily those associated with municipal sewage). The possibility of adapting earlier versions of the *Inventory of Common Air Contaminants* to make them compatible with the 1990 inventory will be investigated as well.
- New sets of weights will be sought for use in aggregating flows of disparate materials. The weights considered for use will include unit damage costs associated with waste flows. These new weights will be used in the production of aggregate material and energy flow indicators along the lines of those described in Annex 5.2 below.
- Longer-term goals include implementing the treatment of durable-good wastes proposed in 4.3.3, regionalising the accounts to the provincial/territorial level, and elucidating the relationship between material and energy flows and the other stocks and flows measured in the CSERA.

Annex 4.1
Statistics Canada's Input-Output Accounts

The accounting framework of Statistics Canada's Input-Output Accounts is shown in Figure A4.1. Before describing the elements of the framework, it is helpful to define several terms.

Commodities, as defined in the input-output framework (and in the CSNA in general), are goods or services that are traded in the economy in exchange for money. Haircuts and automobiles are both commodities for example. In contrast, coal in the ground is not a commodity; it must first be extracted and sold to qualify as such. It is worth emphasising that a transaction must occur between a buyer and a seller for a particular good or service to be considered a commodity in the Input-Output Accounts. This means that water pumped directly from a lake for use in cooling an industrial process does not represent a commodity flow (because no money exchanges hands as a result of its use). On the other hand, drinking water bought at a supermarket does represent a commodity flow, by virtue of the market transaction that takes place when it is bought. Thus, the same material (water in this case) can be both a commodity and a non-commodity depending upon the circumstances of its use.

Industries are groups of establishments producing the same or similar goods or services for sale on the market with the intention of generating profit. All the establishments in Canada that produce cars and trucks, for example, are grouped together to form the motor vehicle industry. All industries, when taken together, comprise what is known as the business sector. Crown corporations that behave essentially like private enterprises, such as VIA Rail, are considered to be part of the business sector. Other public institutions (hospitals, schools, universities) that receive the major part of their funding from government and that do not operate with a profit motive are not considered part of the business sector (they are treated as part of the government sector instead).

Persons are defined as private citizens[1] in their role only as consumers of goods and services; persons are not considered to produce commodities.

Governments are defined as either federal, provincial or municipal public administrations and the related services they offer. These include defence, construction and maintenance and operation of public infrastructure (roads, sewage treatment plants, airports), the provision of social services (health, education and welfare) and municipal services (snow clearing, waste collection, etc.).

Final consumption is said to have occurred when a commodity is consumed in such a way that it is no longer available for further transformation by a domestic industry. Several categories of final consumption (or final demand as it is also known) are defined in the framework.

- **Personal expenditure** is defined as the expenditures on goods and services by persons (private citizens and non-profit organisations). These expenditures are considered final because a commodity purchased by, for example, a household is no longer available to industry for further transformation.
- **Fixed capital formation** is defined as expenditure on goods with operating lives of more than one year. This includes expenditures on machinery and equipment as well as expenditures on built infrastructure (buildings, roads, dams, pipelines, etc.). Such expenditures are considered final because capital goods are not themselves the subject of further transformation in the economy. Rather, the services they provide act as inputs into the transformation of other materials.[2] Fixed capital formation is classified according to the sector undertaking the expenditure (business or government) and type of good (machinery/equipment or construction).
- **Net additions to inventories** measure the value of semi-finished and finished goods added to inventories held by businesses less the value of those withdrawn during a year.[3] Goods added to inventories represent final consumption, because they are no longer available for further processing. Goods removed from inventories and put back into production act as a source of domestic supply and, therefore, represent *negative* final consumption (because they are a source of commodities to the domestic economy rather than a consumer of domestically produced commodities).
- **Government current expenditure** is defined as the expenditure of all levels of government on current account for goods and services. (Capital expenditures of governments are included as part of fixed capital formation.) These expenditures are classified according to four purposes: education, health, defence and "other".
- **Exports** measure the sales of Canadian goods in foreign countries. Because goods that are exported are no longer available for further transformation in the *domestic* economy, exports are considered final consumption (although the exported goods may undergo further processing in the importing country).
- **Imports** are the expenditures on foreign-produced goods and services by Canadians. Just like withdrawals from inventories, imports are a form of negative final demand because they compete with the output of domestic industries rather than consuming this output.

1. The personal sector is also defined also to include non-profit organisations (religious groups, labour unions and social clubs for example).
2. These services are not treated as final consumption in the Input-Output Accounts, but as current consumption of businesses. They are measured as capital consumption allowances.
3. Note that changes in the value of inventories due to price changes are not included in the Input-Output Accounts.

Figure A4.1
Statistics Canada's Input-Output Accounting Framework

		Production of:	Consumption by:							
		Commodities (1 ... m)	Industries (1 ... n)	Final demand (*F*) (1 ... f)						Total
				Personal expenditure (1 ... h)	Fixed capital formation (1 ... k)	Net additions to inventories	Government current expenditure (1 ... g)	Exports	Less imports	
Consumption of:	Commodities (1... m)		*U*	*H*	*K*	*i*	*G*	*x*	*(m)*	*q*
	Primary inputs (1 ... p)		*YI*	*YF*						*n*
Production by:	Industries (1 ... n)	*V*								*g*
	Total	*q´*	*g´*	*e*						

Notes:
Lower case italicised letters indicate vectors or scalars; upper case italicised letters indicate matrices.
The elements of the framework are defined as follows:
matrix V, the **make matrix**, shows the value of the commodities produced by industries;
matrix U, the **use matrix**, shows the value of commodities purchased by industries;
matrix F, the **final demand matrix**, shows the value of the commodities purchased by the various categories of final demand category; this matrix comprises six sub-matrices and sub-vectors:
matrix H shows the value of personal expenditures of persons and non-profit organisations on commodities;
matrix K shows the value of fixed capital formation;
vector i shows the value of net additions of goods to inventories;
matrix G shows the value of gross government current expenditures on commodities;
vector x shows the value of commodity exports (including exports of previously imported goods);
vector m shows the value of commodity imports (note that the values in this vector are negative, as commodity imports represent negative final demand);
matrix YI shows the value of primary inputs (labour and capital) used by industries;
matrix YF shows the value of primary inputs (labour and capital) used by final consumers (persons and governments);
vector q, the **commodity output vector**, shows the total value of commodities purchased by industries and final consumers; elements in this vector are formed from the row summations of matrices *U* and *F*;
vector g, the **industry output vector**, shows the total value of each industry's production; elements in this vector are formed from the column summation of matrix *V*;
vector n shows the total value of primary inputs used in the economy (the sum of this vector is the income-based estimate of Gross Domestic Product);
vector e shows the total value of final expenditures in the economy (the sum of this vector is the expenditure-based estimate of Gross Domestic Product);
vector q´ is the transpose of vector *q*;
vector g´ is the transpose of vector *g*.
Source:
Modified from Statistics Canada (1987).

Having defined these terms, the structure of the accounting framework presented in Figure A4.1 can now be described.

First, it is important to recognise that Figure A4.1 is a collection of matrices, vectors and scalars; each italicised letter (or group of letters) in the figure represents one of the three. To help the reader distinguish among these elements, vectors and scalars are labelled with lower case italicised letters and matrices with upper case italicised letters. A "prime" on a vector or matrix label (*q´* for example) simply indicates that the element is the transpose of another element found elsewhere in the framework. The dimensions of any vector or matrix can be determined by consulting the row and column headings to the left and above the element. The dimensions of matrix *U*, for example, are found to be m x n using this method.

The number of commodities in the framework is represented by the variable "m", where m is either 627, 485, 100 or 49 depending upon the level of aggregation of the accounts. Every good and service sold in the Canadian economy is represented among these m commodities, regardless of the value of m. The higher the value of m, the greater the detail with which commodities are represented in the framework. At the most detailed level (m=627), the framework distinguishes 22 different agricultural commodities; these same 22 commodities are collapsed into just two at the least detailed level (m=49).

The number of industries in the framework is represented by "n", which takes values of 216, 161, 50 or 16 depending upon the level of aggregation of the accounts. As with commodities, the n industry groups are defined to represent every industry in the economy. At the most detailed level of the framework, where the business sector is divided into 216 industries, the detail is substantial. Mining, for example, is split into 11 different industries at this level. In contrast, all mining activity is grouped into a single industry at the highest level of aggregation (n=16).

There are "f" categories of final demand represented in Figure A4.1, where f is either 136, 28 or 14 depending upon the level of aggregation of the accounts. Depending on the value of f, the various categories of personal expenditure make up one third to one half of the final demand categories (represented by "h" in Figure A4.1). Another one half to two thirds ("k") of the final demand categories are various forms of fixed capital formation. The remaining categories are made up of imports, exports, inventory changes (all of which are uni-dimensional) and government consumption (of which there are "g" categories).

There are three principal matrices in the Input-Output Accounts: the **make**, **use** and **final demand** matrices. These are labelled *V*, *U* and *F* respectively in Figure A4.1.

The **make matrix**, *V*, (dimensions m x n) displays the value of each commodity produced by each industry during a given year. Summation of this matrix across all commodities (that is, along each row) yields the total value of output by each industry, which is represented by vector *g* in the framework.

Industries must of course purchase inputs in order to produce their outputs. The values of industrial inputs (referred to as intermediate inputs) are recorded in the **use matrix**, *U* (dimensions m x n). Matrix *U* displays the value of each industry's intermediate use of each commodity during a given year.

The **final demand matrix**, *F* (dimensions m x f), records the values of commodities purchased for final consumption. As described above, final consumption includes several categories of expenditures. These are labelled in Figure A4.1 as follows:

- matrix *H* (dimensions m x h) - expenditures of persons and non-profit organisations and institutions;
- matrix *K* (dimensions m x k) - expenditures on fixed capital formation;
- vector *i* (dimensions m x 1) - value of physical changes (additions and withdrawals) in inventories;
- matrix *G* (dimensions m x g) - government current expenditures on goods and services;
- vector *x* (dimensions m x 1) - exports; and
- vector *m* (dimensions m x 1) - imports.

All commodities produced in the economy must, by definition, be consumed either as intermediate inputs or for final consumption. Thus, summation of matrices *U* and *F* across industries and final consumers respectively (that is, across their rows) yields the total value of commodity production during the year. This summation, which is represented in the framework by vector *q*, can be expressed algebraically as:

$$\sum_n U + \sum_f F = q \qquad \text{Eq. A4.1}$$

The Input-Output Accounts also record the **primary inputs** (taxes and subsidies, labour, and profits) purchased by businesses, persons and governments.[1] The value of each of these inputs purchased annually by businesses is recorded in matrix *YI* (dimensions p x n). Final consumption of primary inputs by persons/non-profit organisations and governments are recorded in matrix *YF* (dimensions p x f).

Summation of matrices *YI* and *YF* across industries and final consumers (that is, along each row) yields a fundamental measure of the CSNA: total income of each factor of production in the economy (recorded as vector *n*). The summation of this vector, in turn, yields the widely used aggregate economic indicator known as GDP. Because this estimate of GDP derives from the sum of all incomes in the economy, it is referred to as the "income-based" estimate of GDP. Total income is, by definition, equivalent to total expenditure (one person's gain is another person's expense), so it is also possible to estimate GDP by summing all final expenditures in the economy. Vector *e* represents this summation by category of final demand (that is, down the columns of matrices *F* and *YF*). The expenditure-based estimate of GDP is equal to the summation of vector *e*. These relationships can be expressed algebraically as follows:

$$\sum_n YI + \sum_f YF = n \qquad \text{Eq. A4.2}$$

$$\sum_p YF + \sum_m F = e \qquad \text{Eq. A4.3}$$

$$\sum e = \sum n \qquad \text{Eq. A4.4}$$

$$\sum e = \text{GDP (expenditure based)} \qquad \text{Eq. A4.5}$$

$$\sum n = \text{GDP (income based)} \qquad \text{Eq. A4.6}$$

1. It may be unusual for some readers to think of profits (or the return to capital) and taxes as inputs. To national accountants these are charges against income just the same as material inputs and therefore are treated as inputs in the national accounts.

Annex 4.2 Technical details of MEFA indicators

This annex provides technical details of the derivation of the indicators presented in Text Box 4.1 in the introduction to this chapter (and repeated below). Most of these indicators are based on a version of Statistics Canada's input-output model. Because this model figures so centrally in the indicators, it is derived first before discussing the indicators themselves.

Text Box 4.1
Resource and Waste Indicators developed from the MEFA

- resource intensity of industrial by industry
- resource intensity of household consumption
- resource intensity of net exports
- waste intensity of industrial output
- waste intensity of final domestic consumption
- waste intensity of net exports
- renewable energy as a proportion of total energy production
- recycled proportion of total resource use

A4.2.1 Statistics Canada's input-output model

Using data arranged according to the standard input-output accounting framework shown earlier in Figure A4.1, it is possible to define an input-output model that determines industrial output as a function of final consumption and two structural input-output relationships defined for a base year. These relationships define the input requirements of each industry and the allocation of commodity production among industries.

The assumption made regarding industrial input requirements is that the value of each input used by an industry in the base year is fixed in linear proportion to the total value of the industry's production in any year. Given this assumption, the relationship between inputs and production (the so-called production function) for each industry can be stated in matrix form as follows:

$$\sum_c U = Bg \qquad \text{Eq. A4.7}$$

where:

> $\sum_c U$ represents the summation of the commodity use matrix (U) over all commodities for each industry (that is, the total value of commodity inputs by industry);
>
> g is the vector of industrial output; and
>
> matrix B (dimensions m x n) is a matrix in which an element, b_{ij}, is defined to represent the annual value of commodity i purchased per unit value of output of industry j.

Elements in matrix B are referred to as technical coefficients and are calculated as:

$$b_{ij} = \frac{u_{ij}}{g_j} \qquad \text{Eq. A4.8}$$

where:

> u_{ij} is an element of the commodity use matrix (U) representing the annual value of commodity i purchased by industry j; and
>
> g_j is an element of vector g representing the value of the total output of industry j.

Regarding the allocation of commodity production among industries, it is assumed that each industry's observed base-year market share for each commodity is preserved regardless of the level of commodity output. Given this assumption, the relationship between commodity output and industrial output can be stated in matrix form as follows:

$$g = Dq \qquad \text{Eq. A4.9}$$

where vector g is the industrial output vector, vector q is the commodity output vector, and

> matrix D (dimensions n x m) is a matrix in which an element, d_{ji}, is defined to represent the share of the total domestic output of commodity i held by industry j.

Elements in this matrix, referred to as market share coefficients, are calculated as:

$$d_{ji} = \frac{v_{ji}}{q_i} \qquad \text{Eq. A4.10}$$

where v_{ji} is an element of the make matrix (V) representing the value of commodity i produced by industry j and q_i is an element of vector q representing the value of the total domestic output of commodity i.

One final element is required before the model itself can be derived; this is an accounting expression of the balance between the total annual supply of commodities (from domestic production plus imports) and the annual consumption of these commodities by industries and the various categories of final consumption:

$$q + m = \sum_{c} U + \sum_{f} (H + K + i + G + x) \qquad \text{Eq. A4.11}$$

The model can now be derived in two steps. Substitution first for $\sum_{c} U$ in Eq. A4.11 from Eq. A4.7 yields:

$$q = Bg + \tilde{f} + x - m \qquad \text{Eq. A4.12}$$

where $\tilde{f} = \sum_{f} (H + K + i + G)$

Next, substitution for *q* from Eq. A4.9 into Eq. A4.12 yields Eq. A4.13, which upon rearrangement yields the desired model (Eq. A4.15):

$$Dq = g = DBg + D(\tilde{f} + x - m) \qquad \text{Eq. A4.13}$$

$$g(I - DB) = D(\tilde{f} + x - m) \qquad \text{Eq. A4.14}$$

$$g = (I - DB)^{-1} D(\tilde{f} + x - m) \qquad \text{Eq. A4.15}$$

The model specifies industry output (vector *g*) in terms of the market share and technical coefficient matrices (*D* and *B* respectively) and the various elements of final consumption. Matrices *D* and *B* are both easily derived using base-year input-output data organised according to the accounting framework presented in Figure A4.1. Once these fixed coefficient matrices are calculated, Eq. A4.15 can be used to estimate the value of output required from each industry to meet any specified level of final consumption net of imports.

The portion of the model that incorporates the fixed input-output relationships (that is, matrices *D* and *B*) is known as the commodity impact matrix (IM_C):

$$IM_C = (I - DB)^{-1} D \qquad \text{Eq. A4.16}$$

Elements of this n x m matrix, im_{Cij}, are referred as commodity impact coefficients. They represent the value of output required from industry *i* (the "impact" on industry *i*) in order to supply one unit of commodity *j* for final consumption.

This matrix has an important property that is made use of in the development of the resource and waste indicators below. This is the ability to capture both the direct and indirect impacts of final consumption on industrial output. An example is best used to illustrate this property. Consider the purchase of a domestically produced automobile by a final consumer. This purchase requires, of course, that the automobile industry produce the car. This activity is a *direct* impact of the automobile purchase, because it is induced in the industry directly responsible for producing the car. Beyond this direct impact on the automobile industry, a cascading series of secondary, or *indirect*, effects are created for other industries as well. The steel industry, for example, must produce steel to sell to the automobile manufacturer. Iron mines must, in turn, extract iron ore to sell to the steel manufacturer. All three of these industries require fuel and electricity in their processes, which they must purchase from the energy industries. Energy producers themselves require inputs from other industries, which require inputs from still more industries. It is easy to see how the demand for just one automobile sets in motion a long chain of inter-related, indirect industrial effects.

The nature of the commodity impact matrix is such that it captures all the direct and indirect industrial impacts of each commodity purchased by final consumers. That is, each column of commodity impact coefficients in this matrix shows the value of output required from *each* industry–whether directly or indirectly–in order to deliver one unit of a given commodity to final consumers.

When post-multiplied by a vector of final consumption, this matrix yields an estimate of the total industrial production required to meet the level of consumption specified by the vector. If, for example, the commodity impact matrix is multiplied by a vector representing the final consumption of households, the result is an estimate of the value of industrial production required to supply the goods and services purchased by households. Multiplying the matrix by a vector of commodity exports yields an estimate of the value of production devoted to meeting the demand for Canadian products from abroad. If a vector measuring imports rather than exports is used, the result is an estimate of how much domestic production is lost to foreign producers as a result of our imports.[1] Multiplying the commodity impact matrix by a vector of final consumption comprising all the elements of the final demand matrix, as in Eq. A4.15, yields the total value of industrial output (that is, vector *g*).

The commodity impact matrix specified in Eq. A4.16 can be easily transformed into an industry impact matrix (IM_I) by eliminating the post-multiplication by matrix *D* from Eq. A4.16:

$$IM_I = (I - DB)^{-1} \qquad \text{Eq. A4.17}$$

Elements of this n x n matrix, im_{Iij}, are referred to as industry impact coefficients. They represent the value of output required from industry *i* (the "impact" on industry *i*) required for the production of one unit of output from industry *j*.[2] As just

1. The assumption here is that domestic production capacity exists for the imported commodities. There are a few commodities however, referred to as non-competing imports, for which no domestic production capacity exists. These are mainly tropical fruits and other agricultural products that cannot be grown in the Canadian climate. Obviously, no domestic production is displaced by importation of non-competing imports. For all other commodities, it is assumed that Canadian capacity exists to produce the identical commodity or an appropriate substitute.

described for the commodity impact matrix, the industry impact matrix captures both direct and indirect impacts of a unit of industrial production. That is, each column of industry impact coefficients in this matrix show the value of output required from each industry–whether directly or indirectly–in order to produce one unit of output from a given industry.

Having presented and discussed the basic input-output model and associated impact matrix, the discussion now turns to the derivation of the resource and waste indicators.

A4.2.2 Resource intensity of industrial output

Concept

The first indicator listed in Text Box 4.1 is resource intensity of industrial output. This is defined as the annual resource use (measured in physical units) per unit value of output for each industry defined in the MEFA framework. Two components of resource use are measured in this indicator. First, there are the resources consumed directly in the production processes of a given industry. In addition to this direct resource consumption are the resources “embodied” in the commodities that the industry uses as inputs to its production processes. The latter represent the industry’s indirect resource consumption. Although not directly consumed by the industry, embodied resources are implicitly associated with its production and therefore must be included in the indicator. It should be noted that it is not just the resources embodied in domestic commodities used by the industry that are measured in this indicator, but also those embodied in its imported inputs. The latter cannot be neglected. To do so would be to present an incomplete picture of industrial resource intensity. For example, if there was an increasing tendency by an industry to purchase resource-intensive inputs from foreign suppliers, it would be misleading to allow this trend to indicate a reduction in the industry’s resource intensity over time. Yet this is exactly what would happen if the embodied resources in foreign-supplied inputs were neglected in the indicator.

The possibility of weighting disparate material flows to allow their aggregation was discussed in the Introduction to this chapter. Currently, weights that would allow this do not exist.[1] In the absence of such weights, it is not possible to sum all resource flows to arrive at a single, aggregate indicator of the resource intensity of output. For this reason, not one but several resource intensity indicators are developed from the MEFA, and they are limited to those resources that can be meaningfully aggregated without need for weights:

- energy intensity by industry;
- water intensity by industry; and
- wood intensity by industry.

Derivation

The first step in the derivation of the indicators of resource intensity of industrial output is to define *direct* energy, water and wood intensity coefficients for each industry. These can be expressed as:

$$\alpha_x = \frac{U_{ru_x}}{g'} \qquad \text{Eq. A4.18}$$

where:

α_x is a 1 x n vector of industrial direct resource intensity coefficients for energy, water or wood in which elements, α_{x_i}, represent the annual quantity of resource *x* ($x \in$ energy, water, wood) used directly per unit value of output by industry *i*;

vector U_{ru_x} is a row taken from the industrial resource use matrix representing the quantities of energy, water or wood used by each industry in a given year; and

vector g' is the 1 x n row vector of industrial output defined to be the transpose of vector *g.*

The next step in the derivation is to pre-multiply the industry impact matrix (IM_I) defined in Eq. A4.17 with vectors of industrial direct resource intensity coefficients for energy, water and wood:

$$\alpha_x(I - DB)^{-1} \qquad \text{Eq. A4.19}$$

Recalling that the industry impact coefficients derived from Eq. A4.17 measure the value of output from industry *i* required for the production of one unit of output from industry *j*, and that they capture both direct and indirect industrial impacts, it can be shown that Eq. A4.19 is sufficient to derive the desired resource intensity indicators.

First of all, the coefficients that result from Eq. A4.19 measure both direct and indirect resource use per unit of output for each industry. That this is so can be shown with a simple three-industry example using energy as the resource:

$$\begin{bmatrix}\alpha_{e1} & \alpha_{e2} & \alpha_{e3}\end{bmatrix}\begin{bmatrix} im_{I11} & \dots & \dots \\ im_{I21} & \dots & \dots \\ im_{I31} & \dots & \dots \end{bmatrix} = \left[\alpha_{e1} im_{I11} + \alpha_{e2} im_{I21} + \alpha_{e3} im_{I31}\right.$$

Space permits only a portion of this matrix multiplication to be shown, but this is sufficient to illustrate the result. The im_I coefficients represent the output required from industries 1 through 3 per unit of production from industry 1. The α_e co-

2. In fact, the commodity impact coefficients calculated in Eq. A4.16 are simply weighted averages of the industry impact coefficients, with market-share coefficients (matrix *D*) used as the weights.
1. To date, the focus of the scientific community has been the development of weights for waste materials.

efficients represent the direct use of energy per unit of output from industries 1 through 3. Multiplication of these two sets of coefficients (following standard rules of matrix multiplication) yields the following sum: the use of energy per unit of output of industry 1 due to industry 1's impact on itself (that is, industry 1's direct energy use) **plus** the indirect use of energy per unit of output of industry 1 due to industry 1's impact on industry 2 **plus** the indirect use of energy per unit of output of industry 1 due to industry 1's impact on industry 3. The sum of these three elements is the total direct and indirect energy requirements per unit of output from industry 1. The same result would be achieved for industry 2 and 3 if the full multiplication were carried out. Thus, Eq. A4.19 satisfies the requirement that the indicators of resource intensity of output capture both direct and indirect resource use for each industry.

The other major requirement of the indicator is that it capture the indirect resource use associated with both domestic and imported inputs purchased by industries. The nature of the industry impact matrix (IM_I) is such that Eq. A4.19 does this. This is because no allowance is made in the derivation of the industry impact matrix for displacement of domestic production by imported commodities. That is, the matrix was specified as though Canada's economy were closed to imports and all commodities were supplied domestically. This results in domestic industry impact coefficients that are inflated to compensate for the missing imports, which in turn means that Eq. A4.19 results in industrial resource intensity coefficients that compensate for the foreign resource consumption embodies in imported inputs.[1]

One final point must be made with respect to Eq. A4.19: the industry impact matrix (IM_I) must be specified in constant (or inflation adjusted) prices. This is so that the effect of inflation on the value of industrial output is removed from the indicators, an adjustment that is very important if they are used to monitor changes in resource intensity over time. If the impact matrix were specified in current prices, the general upward trend in the value of output due to inflation would artificially force resource intensity downward over time. This would obscure the important movements in resource intensity due to changes in technological and economic structure that the indicators are intended to measure. This point applies will equal force to all of the indicators described in this Annex that make use of monetary denominators.

1. It is important to recognise the assumption implicit in this method of estimating embodied foreign resource use. Foreign industries are assumed to have the same production functions as Canadian industries. That is, the resource requirements to produce one unit of a given industry's output are assumed to be the same in Canada as they are in the nations with which we trade. The distortional effect of this assumption on the indicators is moderated by the fact that some of our trading partners are likely to be more resource intensive than Canadian industries while others will be less so. Moreover, the bulk of Canadian foreign trade is with the United States, for which the assumption of similar resource intensities is reasonable.

A4.2.3 Resource intensity of household consumption

Concept

The next indicator listed in Text Box 4.1 is resource intensity of household consumption. This indicator is defined as the quantity of resources (measured in physical units) used per unit value of household consumption. The same set of three indicators defined above for industries are also developed for households:

- energy intensity of household consumption;
- water intensity of household consumption; and
- wood intensity of household consumption.

As was the case for industries, two categories of household resource use are included in these indicators: resources used directly by persons (drinking water and home heating fuel for example) and resources embodied in the commodities (both domestic and imported) that they purchase.

Derivation

The indicators of resource intensity of household consumption are derived by summing direct household resource use with indirect household resource use and dividing the sum by the total value of household consumption. Direct household consumption of energy, water and wood is calculated by summing the appropriate rows from the household resource use matrix (H_{ru}):

$$\text{direct household resource use} = \sum_h H_{ru_x} \qquad \text{Eq. A4.20}$$

where H_{ru_x} is a row from the household resource use matrix representing the consumption of resource x ($x \in \text{energy, water, wood}$).

Indirect resource use by households is calculated by taking advantage of the capacity of the commodity impact matrix (IM_C) to capture the direct and indirect industrial impacts of each commodity purchased by final consumers. Just as premultiplying the industry impact matrix (IM_I) by a vector of direct industrial resource coefficients yielded a measure of the direct and indirect resource intensity of industrial output in Eq. A4.19, premultiplying the commodity impact matrix (IM_C) by the same vector yields a measure of the direct and indirect resource intensity of commodity output:

$$\text{resource intensity of commodity output}_x = \alpha_x (I - DB)^{-1} D \qquad \text{Eq. A4.21}$$

As noted above, post-multiplication of the commodity impact matrix with the vector of household consumption (H) yields an estimate of the industrial output required to supply the goods and services purchased by households. Similarly, post-multiplying Eq. A4.21 by the vector of household consumption yields an estimate of the resources consumed by industries in supplying these same goods and services. This is the indirect resource use of households:

$$\text{indirect household resource use}_x = \alpha_x (I - DB)^{-1} DH \quad \text{Eq. A4.22}$$

Having defined measures of direct and indirect household resource consumption, the desired indicators of resource intensity of household consumption can be calculated as the sum of Eq. A4.21 and Eq. A4.22 divided by the total value of household consumption:

$$\text{resource intensity of household consumption}_x = \frac{\sum_h H_{ru_x} + \alpha_x (I - DB)^{-1} DH}{\sum_c \sum_h H} \quad \text{Eq. A4.23}$$

As was the case with the indicators of resource intensity of industrial output, Eq. A4.23 estimates the indirect resource consumption of households associated with their consumption of both domestic and imported goods and services.

A4.2.4 Resource intensity of net exports

Conceptual issues

The third indicator listed in Text Box 4.1 is resource intensity of net exports. This is defined as the annual quantity of resources required per unit value of Canada's exports less the quantity of resources required per value of our imports. This indicator is a measure of the extent to which Canadians trade resources in association with our total international trade. As with the two indicators just discussed, this indicator includes both our direct imports and exports of resources, as well as the indirect resource "imports" and "exports" embodied in the semi-finished and finished goods that we exchange with our trading partners.

Again, three indicators of the resource intensity of net exports are developed:

- energy intensity of net exports;
- water intensity of net exports; and
- wood intensity of net exports.

These indicators have positive values if Canada is a net exporter of resources in association with its international trade and negative values if the opposite is true. For example, if more water is required per unit of our exports (either directly or indirectly) than is required per unit of production for the commodities that we import, then the water intensity of our net exports will be positive.

Derivation

Resource intensity of net exports is calculated in the same manner as resource intensity of household consumption. Indirect resource use associated with the net exports is calculated by postmultiplying Eq. A4.21 with the vector of net exports (x - m). Direct net resource exports are calculated as the difference between the resource export vector (x_{ru}) and the resource import vector (m_{ru}). The sum of direct plus indirect resource use associated with net exports is divided by the total value of net exports to arrive at the desired indicator:

$$\text{resource intensity of net exports}_x = \frac{(x_{ru_x} - m_{ru_x}) + \alpha_x (I - DB)^{-1} D(x - m)}{\sum_c (x - m)} \quad \text{Eq. A4.24}$$

A4.2.5 Waste intensity indicators

The same three indicators that have just been discussed with respect to resources are also developed for waste flows:

- waste intensity of output by industry;
- waste intensity of household consumption; and
- waste intensity of net exports.

Concept

The concepts surrounding the waste intensity indicators are identical to those already discussed for the resource indicators and will not be repeated. It is necessary however to mention the specific waste categories for which each of the above indicators is developed:

- greenhouse gases (carbon dioxide, methane and nitrous oxide);
- acid rain-causing gases (oxides of sulphur and nitrogen);
- ozone depleting substances (chlorofluorocarbons, halons, carbon tetrachloride and trichloroethane); and
- nutrient wastes (nitrogen and phosphorus).

Scientifically proven weights have been developed that allow the waste flows associated with each of the above categories to be weighted and aggregated into single values that can be used in the development of indicators (see, for example, the discussion of global warming potential in Section 4.2 earlier in this chapter).

Derivation

Waste intensity of output by industry - The derivation of these indicators is essentially identical to that of the corresponding resource use indicators (Eq. A4.19). The only difference is that the direct resource use coefficients (α_x) are replaced with direct waste output coefficients:

$$\text{waste intensity of industrial output}_x = \beta_x (I - DB)^{-1} \quad \text{Eq. A4.25}$$

where β_x is a vector of industrial direct waste output intensity coefficients in which elements, β_{x_i}, represent the annual quantity of aggregate waste x ($x \in$ greenhouse gases, acid gases, ozone depletors, nutrients) produced directly per unit value of output from industry *i*.

Waste intensity of household consumption - Again, the derivation of these indicators is identical to that of the corresponding resource use indicators (Eq. A4.23). The only changes are the substitution of vector β_x (as just defined) for vector α_x, and the substitution of the matrix of household waste production (H_{wp}) for the matrix of household resource use (H_{ru}):

$$\text{waste intensity of household consumption}_x = \frac{\sum_h H_{wp_x} + \beta_x (I - DB)^{-1} DH}{\sum_c \sum_h H} \quad \text{Eq. A4.26}$$

Waste intensity of net exports - These indicators are also derived following their resource-use equivalents (Eq. A4.24), with the substitution of vector β_x for vector α_x and of the vectors of waste imports (m_{wu}) and exports (x_{wu}) for the vectors of resource imports and exports:

$$\text{waste intensity of net exports}_x = \frac{(x_{wu_x} - m_{wu_x}) + \beta_x (I - DB)^{-1} D(x - m)}{\sum_c (x - m)} \quad \text{Eq. A4.27}$$

A4.2.6 Renewable energy as a proportion of total energy production

Concept

The next indicator defined in Text Box 4.1 is defined as the percentage of total Canadian energy production in a year that comes from renewable sources. Renewable energy is defined to include hydroelectric power, other renewable forms of electric power (wind, tidal, solar), biomass (wood and wood wastes and other biomass wastes), and solar energy consumed directly for heating purposes.

The renewable share of total energy production is considered an important indicator of sustainability for two reasons. First, by definition the environment cannot indefinitely supply non-renewable energy sources and, therefore, the only sustainable energy path in the long-run is conversion to renewable sources. Of more immediate concern is the fact that the environment's capacity to absorb the waste materials associated with fossil fuels (which are the main non-renewable energy source today) has already been exceeded with a number of well-known negative consequences: acid rain, urban smog and climate change to name a few. Given that renewable sources produce less (or none) of these wastes per unit of energy than non-renewable fossil fuels,[1] environmentally sustainable energy consumption again points toward conversion to renewable sources.

Derivation

Renewable energy as a proportion of total energy production is calculated as the sum of renewable energy production by industries, households and governments divided by their total energy production (renewable and non-renewable):

$$\text{renewable share of total energy production} = \frac{\sum_n V_{rp_{re}} + \sum_h H_{rp_{re}} + \sum_g G_{rp_{re}}}{\sum_n V_{rp_{te}} + \sum_h H_{rp_{te}} + \sum_g G_{rp_{te}}} \quad \text{Eq. A4.28}$$

where:

$V_{rp_{re}}$, $H_{rp_{re}}$ and $G_{rp_{re}}$ represent, respectively, the columns of the industrial, household and government resource production matrices in which the production of **r**enewable **e**nergy commodities are recorded; and

$V_{rp_{te}}$, $H_{rp_{te}}$ and $G_{rp_{te}}$ represent, respectively, the columns of the industrial, household and government resource production matrices in which **t**otal **e**nergy production is recorded.

1. Recent studies indicate the possibility that flooding of land associated with hydroelectric reservoirs may result in significant greenhouse gas emissions. This suggests that the conversion to this form of renewable energy may not be as environmentally sustainable as once thought.

A4.2.7 Recycled proportion of total resource use

Concept

The final indicator remaining to be discussed is the recycled proportion of total resource use. This indicator is defined as the proportion of annual industrial resource use that is met by recycled waste materials.

Of course, not all resources are recyclable and of those that are technically recyclable, not all are currently recycled. For some resources recycling is technically impossible, either of the materials do not lend themselves to being recycled (energy commodities for example) or because the way in which they are used renders them too difficult or too costly to recover (most non-metallic minerals fall into this category). Other resources are of such low value and/or are so abundant that there is no economic incentive for their recycling. For these reasons, recycling indicators are developed only for the following resources:

- ferrous metals;
- aluminum;
- other nonferrous metals;
- water; and
- wood fibre.

Derivation

This indicator is calculated as a simple ratio between recycled use and the sum of recycled plus virgin use for each of the resources listed above:

$$\text{recycled proportion of total resource use}_x = \frac{\sum_n U_{ru_x}^{\text{recycled}}}{\sum_n U_{ru_x}^{\text{recycled}} + \sum_n U_{ru_z}^{\text{virgin}}} \qquad \text{Eq. A4.29}$$

where $\sum_n U_{ru_x}^{\text{recycled}}$ represents the sum of recycled waste material x used by all industries ($x \in$ ferrous metal, aluminum, nonferrous metal, water, wood fibre) and $\sum_n U_{ru_x}^{\text{virgin}}$ represents the use of resource x in virgin form by all industries.

5 Environmental Protection Expenditure Accounts

Introduction

The Environmental Protection Expenditure Accounts (EPEA) are the final component of the environmental and resource accounts described in this volume. The EPEA present an annual time-series of current and capital expenditures on environmental protection. The starting date of the time-series varies by expenditure category; the majority commence in the early 1970s or 1980s, although some series extend back to the mid-1960s. Expenditure estimates are presented at the national level and for each province/territory.

The EPEA comprise three accounts, one for each sector of the economy:

- household expenditures on environmental protection;
- government current and capital expenditures on environmental protection, plus intergovernmental and intersectoral government transfer payments; and
- business capital and operating[1] expenditures on environmental protection.

Where possible, capital expenditures are distinguished from current expenditures, and transfer payments are reported separately from other expenditures.

5.1 Rationale, uses and linkages

Environmental protection expenditures, sometimes referred to as "defensive expenditures,"[2] are one measure of society's response to the negative environmental effects of economic activity. They represent the financial contribution of each sector to preventing and limiting these impacts. Such measures are of interest for several reasons.

- By definition, environmental protection expenditures represent outlays that yield no immediate *economic* benefits.[3] Consequently, it is useful to distinguish them from other expenditures when analysing economic growth.
- Environmental protection expenditures are costly and may divert funds from other uses. They thus impose a financial burden on the economy that should be measured. To the extent possible, this burden should be compared to the benefits gained in terms of a lessening of the impact of economic activity on the environment.
- Environmental protection expenditures show, from a demand-side perspective, the contribution of environmental protection activities to Canada's economy. Considered another way, they represent the size and characteristics of the Canadian demand for goods and services produced for environmental protection purposes. The nature of this demand has been the subject of considerable interest in recent years, as innovative solutions to environmental problems can create valuable markets for Canadian firms, both domestically and abroad.

Although it is tempting to view environmental protection expenditures as an indicator of environmental commitment, this interpretation is not always valid. The environment can be protected in many ways, not all of which result in identifiable and measurable "environmental protection" expenditures. For example, although new technologies often have significant environmental benefits, investments in these technologies are most likely to be justified on economic grounds and thus not considered "environmental protection expenditures" by businesses. This problem and the difficulties it poses for the measurement of environmental protection expenditures are discussed more fully in Section 5.2.1.

5.1.1 Uses

The EPEA serve a number of uses. Most obviously, they represent a means of measuring the financial cost associated with compliance with Canadian environmental regulations and conventions. Some would argue that this cost represents the price of maintaining environmental "well-being" and that, as such, it should not be included in the value of economic output as measured by GDP. Environmental protection expenditures should be excluded, they would argue, on the grounds that they do not contribute to welfare, but simply prevent its decline. The EPEA have been developed, at least in part, to provide those who might be interested in calculating an environmentally-adjusted GDP along these lines with the information necessary to do so.

For its part, Statistics Canada uses the EPEA to produce a set of environmental protection expenditure indicators. These indicators represent the expenditures necessary to prevent or to reduce environmental degradation associated

1. The use of "operating expenditures" in the business account is synonymous with the use of "current expenditures" elsewhere in the EPEA. Operating expenditures is standard terminology when discussing business activities.
2. The term "defensive expenditure" is used in the literature to describe an expenditure undertaken to maintain a given level of welfare or to defend against a decline in welfare. All other expenditures are assumed implicitly to be welfare-enhancing.
3. This is not to say that environmental protection expenditures do not have longer-term economic benefits, or that they do not have immediate non-economic benefits.

with economic activity. They currently focus on the subset of environmental protection expenditures represented by the pollution abatement and control expenditures of governments and businesses:

- consolidated total government expenditures on pollution abatement and control, 1970/71-1994/95;
- non-consolidated government expenditures on pollution abatement and control by level of government, 1970/71-1995/96;
- government capital and repair expenditures for pollution abatement and control, 1985-1995; and
- business capital and repair expenditures for pollution abatement and control, 1985-1995.

In addition there are other environmental protection expenditures made by businesses. As the scope of the EPEA expands in the future, the range of indicators produced will expand in step.

5.1.2 Linkages

Other components of the CSERA

A relationship exists in theory between the production of wastes measured in the Material and Energy Flow Accounts (Chapter 4) and the expenditures on pollution abatement and control measured in the EPEA; expenditures on equipment to abate pollution should result in measurable reductions in waste emissions. Although this relationship exists in theory, no attempt has yet been made to quantify it by explicitly linking these two accounts. More is said on this point in Section 5.7.3.

International linkages

As mentioned in Chapter 2, many countries have undertaken the development of environmental protection expenditure accounts. Surveys on environmental protection expenditures are conducted by industrial associations in Austria, Germany and the United Kingdom. National statistical offices lead similar work in most other nations of the European Community. Austria, Germany, the Netherlands the United States and Japan have conducted their surveys regularly since the 1970s.[1] Australia began a regular survey in 1990.

Along with the work in individual countries, several international organisations are also contributing to developments in this field. Environmental protection expenditure accounts are main components of both the United Nations' SEEA and the European Community's *European System for the Collection of Economic Information on the Environment* (SERIEE) (Eurostat, 1994a and 1994b).[2] As well, the Organisation for Economic Cooperation and Development (OECD) has developed a pollution abatement and control survey that it uses to collect information from member countries. A question on "nature" protection expenditures has been introduced for the 1996 version of this survey.

The framework for Statistics Canada's EPEA borrows from the work of many of the countries and organisations mentioned above. In particular it has been inspired by Eurostat's SERIEE model.

5.2 Classification issues

Classification of environmental protection expenditures poses serious conceptual and practical challenges. Simply defining these expenditures in such a way that an outlay can be unambiguously classified as an environmental protection expenditure, or not, is a major challenge. Two approaches to solving this problem, one purpose-based and the other technology-based, are described below. Following this, the definition of environmental protection expenditures adopted in the EPEA–a modified version of the purpose-based criterion–is presented.

Another major conceptual challenge is the classification of expenditures according to economic sector. Much effort has been devoted by practitioners in the field to clarifying this issue. Section 5.2.2 describes the principles resulting from this effort and their application in the EPEA. Classification of environmental protection expenditures by environmental domain (that is, the part of the environment that is protected) is discussed in Section 5.2.3.

The practical difficulties faced in classifying environmental protection expenditures are mainly the result of data gaps and inconsistencies. These are noted further below in the discussions of the data sources and methods used for each of the sectoral accounts.

5.2.1 Classification of expenditures

There are two main approaches to measuring the cost of environmental protection. The first approach is to ask organisations how much they spend for the **purpose** of environmental protection. The second approach focuses on **technology**; organisations having made new investments with an environmental protection component or impact are asked to evaluate their costs against a "dirty" benchmark technology. Any positive cost differential is labelled an "environmental protection expenditure," regardless of the actual motivation for the investment. Both criteria are discussed in more detail below.

1. The United States has recently announced that it will no longer conduct its survey on a regular basis.

2. Annex 5.2 describes the environmental protection expenditure accounting framework of SERIEE in more detail.

Purpose as criterion

What distinguishes environmental protection expenditures is *the intent to protect and restore the environment*. As obvious as this point may seem, it must be considered carefully since it is fundamental to defining and implementing the EPEA.

Existing statistical classifications, such as the *Standard Industrial Classification* (SIC) and the *Harmonized Commodity Description and Coding System,* are founded upon the nature or attributes of industries and commodities. The wood industries, for example, are defined in the SIC as those that produce wood products. Similarly, the business services industries are those that sell services to businesses. The fact that the products and services sold by these industries can be used for a variety of purposes is outside the purview of the classification systems. No business service industry is defined, for example, as producing services specifically for the purpose of environmental protection. Moreover, no simple grouping of the components of the above classifications can be used to define environmental protection expenditures or an “Environment Industry.” This will always be the case as long as classifications are predicated upon the inherent attributes of goods and not the purpose to which goods are put.

It is possible that one could construct classification systems based upon purpose, but it is difficult to do so. The purpose to which a commodity is put–or to which an industry devotes its activities–is mostly implicit, whereas the attributes of goods and services are explicit. From the perspective of statisticians, who are not privy to the intentions of the economic agents, classifications based upon explicit attributes are thus more objective and practicable.[1]

Limits to the purpose approach

Many expenditures can be unambiguously identified as serving environmental protection using a purpose-based criterion since their sole purpose is clearly to protect the environment. For example, a catalytic converter on a car serves only to reduce air emissions. Likewise, the only purpose of a settling pond for pulp-mill effluent is to reduce the pollution load before it is released to the environment. Expenditures on these sorts of solutions are referred to here as **end-of-pipe** (EOP), because they treat wastes (or other threats to the environment) after they have been generated.

At the other extreme are investments motivated primarily by cost saving or efficiency improvement, but that happen also to have potential for protecting the environment. Examples include the installation of high-efficiency electric motors and the co-generation of electricity. These **change-in-process** (CIP) investments result in decreased waste production at the source. In such cases, it is often futile to ask whether the purpose of the investment was environmental or economic. It can be either or both, and there can be disagreement within the same company as to the relative importance of each motivation.

Even for governments there can be ambiguity of purpose with respect to environmental protection expenditures. For example, a number of federal and provincial government programs of an environmental nature are reported in public accounts[2] as expenditures for resource conservation and development. The ambiguity arises because it is not generally feasible to distinguish resource conservation from development. This is discussed more fully in Section 5.4.

Given the above, it is clear that an objective measure of all environmental protection expenditures based upon purpose is impossible. One can include with certainty only the unambiguous EOP expenditures. For CIP expenditures, the most that can be done is to establish some guidelines for measurement.

To circumvent the difficulty of collecting information on environmental protection expenditures based on purpose, the United States[3] and Australia (McLennan, 1995) include as environmental protection expenditure the cost of any equipment or infrastructure that is intended *primarily* for environmental protection. The decision is left to the respondent as to what proportion of a given expenditure is aimed exclusively at environmental protection.[4]

Technology as criterion

Some European countries have adopted a **technological** approach to defining environmental protection expenditures. The assumption is that for any investment that improves a firm’s operations from an environmental perspective, there is a reference technology that does not achieve the same environmental effect but that does represent “current practice” in the industry. The difference in cost between the “cleaner” technology and the reference technology is deemed environmental protection expenditure.

This approach is theoretically valid, as it focuses directly on the incremental cost of the environmental characteristics of a technology. This methodology eliminates the need to determine the purpose of the new investment; only the cost of the investment and the cost of the so-called “dirty” alternative are required. The environmental characteristics of the new technology need not even be explicit, as often they are not.

There are two variants of the technological approach. The first one takes into account only the capital costs of the investment, while the second considers both the capital and operating costs.[5] A simple example of the importance of considering both costs is the replacement of a natural gas

1. Having said this, the idea of a classification of activities by purposes, or a “functional classification,” is expressed in Chapter 18 of the SNA93.

2. Public accounts provide information on the revenues and expenditures of federal and provincial/territorial government departments.
3. In the U.S. *Survey of Pollution Abatement Costs and Expenditures.*
4. The United States however has felt compelled to establish some rules-of-thumb to help respondents determine what proportions of their CIP investments are environmental.
5. The second variant, or “cost criterion,” has been developed by the Netherlands Central Bureau of Statistics (Eurostat, 1994b; de Boo, 1993).

space-heater by a solar panel heating system. Since the operating cost of the solar panel is almost negligible, it is important to consider the present value of the future savings in any assessment of the two alternatives. Although the second variant of the technological approach is more complete, its additional information requirements make it less practical.

The major drawback of the technological approach is that there is most often no readily available information on alternative investments. Indeed, reference technologies may exist only in theory. Production facilities are often unique in their scale and configuration, so that a realistic alternative to a proposed investment is difficult, or impossible, to conjecture. Any attempt to compare costs to a hypothetical alternative is meaningless (or, at best, prohibitively expensive) in such cases.

In summary, the technological criterion is preferable in theory to one based upon the determination of purpose. However, severe information constraints make technology as a criterion impractical for most applications.

Narrowing the scope - regulation/convention as a criterion

Since the technological criterion is difficult to implement in practice, the definition of environmental protection expenditures used in the EPEA starts from the purpose criterion. This criterion is made more practical by restricting the purposes that define environmental protection expenditures:

> Only those expenditures undertaken for the purpose of complying with environmental regulations and/or conventions are measured in the EPEA.

The regulation/convention criterion is summarised in Text Box 5.1.

Text Box 5.1

Definition of Environmental Protection Expenditures

Environmental protection expenditures are defined as current and capital expenditures incurred in order to comply with or anticipate environmental regulations or conventions that apply to Canada. Examples of environmental regulations include the *Canada Fisheries Act* regulations on liquid effluents from the pulp and paper, metal mining and petroleum refining industries. Environmental conventions include any formal multi-party commitment to meet specific targets relating to environmental protection. Examples include the Canada-United States *Air Quality Agreement*, the *National Packaging Protocol*, and the *Responsible Care* program adopted by the Canadian Chemical Producers Association.

The following categories of environmental protection expenditures are measured in the EPEA:

- pollution abatement and control (PAC);
- restoration of wildlife and habitat;
- environmental monitoring, assessments and audits; and
- site reclamation and decommissioning.

Expenditures to improve employee health, workplace safety and for site beautification are excluded.

Government regulation serves as a useful guideline in delimiting what is to be included as an environmental protection expenditure. Regulation makes explicit what normally would be implicit. Even if there is a financial advantage to a company in adopting a new technology that contributes to environmental protection, the fact that its adoption is undertaken for the sake of regulatory compliance ensures that there is an overriding environmental motivation.

Regulation is at once too broad and too narrow a criterion however. It is too broad because the reaction to regulation may far exceed the requirements of the law. A company may decide to upgrade an entire process where a less expensive EOP technology might satisfy the terms of the regulation. It is too narrow in that many explicit pollution abatement investments are made without the impetus of regulation. To deal with this latter problem, environmental conventions (or multi-party environmental agreements) have also been included in the criterion defining environmental protection expenditures. This ensures that expenditures made to meet the terms of government-business accords, such as Ontario's *Countdown on Acid Rain*, or unilaterally established industrial conventions intended to forestall regulation, are captured. Given the recent emphasis on voluntary government-business environmental agreements (regulation is no longer the approach of choice), environmental protection expenditures are likely to be triggered more often by conventions in the future.

The adoption of the environmental regulation/convention criterion to define the scope of environmental protection expenditures is useful, but incomplete. While it eliminates investments that are made mainly for non-environmental purposes, it does not fully address the problem posed by investments with multiple purposes (that is, most CIP investments). Respondents are still left to decide what proportion of a multi-purpose expenditure to include as an environmental protection expenditure. This means that, for the time being, Canada's approach to measuring environmental protection expenditures is more in line with that of the United States and Australia than with the approach of European Union countries.

In summary, a regulation/convention criterion has been adopted to define environmental protection expenditures in the EPEA. This principle allows the inclusion of expenditures made in response to, or in anticipation of, requirements of law or voluntary agreements/conventions; it disallows any other expenditures.

5.2.2 Classification by economic sector

The same environmental protection expenditure can often be classified to more than one economic sector, as there is both a financer and an executor for every expenditure.[1] In many cases the financing and executing sector are one and the same, but this is not always so. Consider household waste disposal services. These are typically carried out by local governments, but it is households who finance the services through municipal taxes. Depending upon the perspective taken, the associated expenditures can be classified to either the government sector or to the household sector. Under what is termed the **financing criterion**, they are attributed to households, while the execution or **abater criterion** classifies them to the government sector.

The financing and abater criteria are identical in their treatment of most environmental protection expenditures. A sector's expenditures on own-account environmental protection activities, as well as its expenditures on activities undertaken on its behalf by other sectors, are dealt with in the same fashion. Under both criteria, these expenditures are attributed to the sector making the expenditure. It is only with respect to *intersectoral transfer payments* that the criteria differ.

Under the financing criterion, all transfer payments made by a sector are included in the sector's environmental protection expenditures, while any transfers it receives are netted out of its expenditures. In this way, the financing criterion measures the cost of environmental protection *borne* by the sector, regardless of which sector actually makes the final expenditure for the activity.

The treatment of intersectoral transfers under the abater criterion is exactly the opposite. The abater criterion includes transfer payments received from other sectors, while subtracting transfer payments made to other sectors. Thus, the abater criterion attributes environmental protection expenditures to the sector in which the expenditures are actually made, regardless of which sector originally finances the outlays.[2]

1. The distinction between the financer and executor of environmental protection expenditures has been made by the OECD, among others, in its pollution abatement and control accounting framework (Organisation for Economic Cooperation and Development, 1993).
2. The definition of the abater criterion presented here corresponds with that used by the OECD since 1994 in its survey of pollution abatement and control expenditures. A second version of the abater criterion exists and should be noted. This version, based on an earlier OECD definition (Organisation for Economic Cooperation and Development, 1993), measures the expenditures on environmental protection activities actually executed by a sector (McLennan, 1995). Thus, rather than measuring the burden of, or demand for, environmental protection in a sector, this criterion measures the production of environmental protection activities that occurs in the sector.

It is important to note that no matter which criterion is used, the total environmental protection expenditure measured is the same. It is only the allocation of expenditures among sectors that changes.

In order to avoid double counting in the EPEA, it is necessary to distinguish the executor from the financer of the environmental protection expenditures and to classify expenditures according to one or the other of the above criteria. Indeed, since each criterion presents a useful perspective on environmental protection expenditures, the ideal situation would be to have two versions of the EPEA, one following the financing criterion and another following the abater criterion. An EPEA following the financing criterion would be of interest to those wishing to know where the financial burden of protecting the environment falls. A set of accounts following the abater criterion, in contrast, would be of interest to those who need to know where the demand for environmental protection goods and services originates.

Strict application of the financing and abater criteria in the EPEA is made difficult by gaps and inconsistencies in the available data, particularly with respect to intersectoral transfer payments. In practice, whichever criterion is implicit (by the treatment of transfers) in a given set of environmental protection expenditure data is the one that is applied in the accounts. As a consequence, the criterion used varies from one sector to another, making it difficult to aggregate the sectoral sub-accounts into a consolidated EPEA.

When measuring a sector's environmental protection expenditures, regardless of the criterion applied, any revenues or savings generated by the sale of by-products must be subtracted from cost of protection activities. For example, the revenues generated for the government from the sale of recyclable household wastes must be subtracted from government expenditures on solid waste management (assuming that the abater criterion is in effect). It is not always straightforward to obtain the information necessary to do this however; special surveys are normally required.

5.2.3 Classification by environmental domain

Environmental protection expenditures can also be classified by environmental domain, or the part of the environment that is protected. This is done in SERIEE for example, where the *European Standard Classification of Environmental Protection Activities* is used. Text Box 5.2 presents SERIEE's classification of expenditures by environmental domain.

In practice, the level of detail available on environmental protection expenditures does not always allow classification by environmental domain (as seen in the following sections). There is no satisfactory solution to this problem, especially since environmental regulations and conventions tend less and less to be domain-specific. In any case, classification by environmental domain is not completely satisfactory, as wastes do not remain in the medium to which

Text Box 5.2
SERIEE Classification of Environmental Protection Expenditures by Environmental Domain

- ambient air and climate protection
- wastewater management
- solid waste management
- protection of soil and groundwater
- noise and vibration
- protection of biodiversity and landscape: protection of species, landscapes and habitats including forest protection (landscape and forest protection are excluded unless they are undertaken to protect forests and landscapes from human activities)
- other environmental protection activities: protection against radiation; environmental R&D; education and training related to environmental protection; general environmental administration

they are released. Air emissions are eventually deposited on land or water and contaminants released into streams and rivers ultimately find their way into groundwater. Nonetheless, the distinction is still useful, if for no other reason than that it provides market information for broad categories of pollution abatement equipment. It is thus maintained in the EPEA wherever the data allow.

5.3 Business account

The business account of the EPEA is restricted to expenditures made by firms to limit the negative environmental effects of their production activity.[1] The regulation/convention criterion is used to define the scope of environmental protection expenditures that are measured for businesses. For certain expenditures, classification by environmental domain is available. Capital and operating expenditures are reported separately.

Environmental protection expenditures in the business sector are classified according to the categories outlined in Text Box 5.3. Pollution abatement and control (PAC) expenditures include the following:

- the purchase of waste and sewage management services from governments or private contractors;
- expenditures on EOP construction and equipment; and
- CIP expenditures.

Other environmental protection expenditures measured for businesses include:

- site clean-up and decommissioning;
- environmental monitoring, assessments and audits;
- wildlife and habitat protection activities;
- fees, fines and licences; and
- “other” expenditures.

5.3.1 Data sources and methods

Annex 5.1 summarises the various data sources used to collect information on environmental protection expenditures in the business sector. In general, the data available from these sources share the following characteristics:

- the data are collected through surveys, only some of which are designed specifically to collect environmental protection expenditure information;
- in some instances the data represent only a subset of environmental protection expenditures; for example, information may be unavailable by province, or it may focus only on specific categories of expenditures;
- data from different surveys are not always compatible with one another because of different coverage periods, classifications, levels of detail or collection methods;
- the data are difficult to classify because of the multi-purpose nature of certain expenditures (such as CIP expenditures for PAC).

The inconsistencies in these sources present challenges when integrating the data into a single set of statistics. Although compensating adjustments are made to the extent possible, users of the EPEA should be aware of these inconsistencies when comparing environmental protection expenditures taken from various sources.

Capital expenditures by businesses

An annual time-series of PAC capital expenditures based on results from the *Capital and Repairs Expenditure Survey* (CRES) exists for the period 1985 to 1995 inclusive. This survey covers the entire business sector. Respondents to the survey are asked to provide data on capital expenditures by type of asset, several of which pertain specifically to pollution abatement and control (Text Box 5.3). Note that no specific criterion is used to define PAC expenditures in the CRES; the decision to include an investment under the PAC category is left to the respondent. As a result, the survey likely under-values PAC capital expenditures; establishments may prefer to declare their investments under other asset categories.

1. Future work regarding the collection of supply-side information on producers of environmental protection activities is discussed in Section 5.7.1.

Text Box 5.3

Classification of Environmental Protection Expenditures - Business Sector

1. Classification of expenditures from the *Capital and Repairs Expenditure Survey* (PAC expenditures for 1985-1995)

- PAC construction and equipment
- waste disposal facilities
- construction of sewage networks: sewage treatment and disposal plants including pumping stations; sanitary and storm sewers, trunk and collection lines, open storm ditches and laterals; lagoons, and any other sewage system construction
- mine tailing disposal systems, including settling ponds
- sanitation equipment

2. Classification of expenditures from the *Survey of Environmental Protection Expenditures* (capital and operating expenditures)

- environmental monitoring: expenditures related to equipment, labour and purchased services required for the monitoring of pollutant emissions that may affect air, water or soil quality
- environmental assessments and audits: expenditures for reviews of current operations for compliance with regulations, and expenditures to evaluate the environmental impact of proposed projects
- site reclamation and decommissioning: expenditures to clean up environmental damage from previous activities and expenditures for site closure
- wildlife and habitat protection: expenditures made to protect wildlife and habitat from the effects of economic activity or to restore stocks that have been adversely affected by such activity
- purchase of waste and sewage management services from a private contractor or a government body
- EOP PAC expenditures: expenditures for which the sole purpose is to abate or to control undesirable substances emitted during regular production activities; EOP installations do not affect the production process itself
- CIP PAC expenditures: expenditures that lead to a new or significantly modified production process in order to prevent or reduce emissions of pollutants and the amount of waste generated
- environmental fees, fines and licences
- other environmental protection expenditures: the costs of administering environmental projects and providing environmental training for example

Total capital and repair expenditures on PAC construction and equipment are available by industry and by province from the CRES. A breakdown by type of PAC asset is available at the national level only however, and only for major industrial divisions (total manufacturing and total mining for example) because of the need to maintain respondent confidentiality.

Given the shortcomings of the CRES as a source of environmental protection expenditure data, a specific *Environmental Protection Expenditure Survey* (EPES) has been launched by Statistics Canada. This survey fills important data gaps regarding capital and operating expenditures on environmental protection. A pilot survey was run for the reference year 1989 (the *1989 Pollution Abatement and Control Survey*), which provided information for comparison with the CRES. The additional data collected by the *Pollution Abatement and Control Survey* covered capital expenditures on EOP PAC facilities and equipment by type of pollutant. The survey covered all industries, but was restricted to those firms having reported PAC expenditures to the CRES in the previous three years. The survey deliberately avoided the question of CIP investments and did not request information on other environmental protection expenditures (such as environmental assessments and site remediation).

Based on the results of the 1989 pilot survey, important conceptual issues were refined and the more complete *Environmental Protection Expenditure Survey* was devised. It was implemented for the first time for the reference year 1994.[1] This survey collected detailed data on capital expenditures for environmental protection for a range of primary and manufacturing industries. The environmental regulation/convention criterion was explicitly used to define environmental protection expenditures. Respondents were left to decide themselves what proportion of multi-purpose investments to report. The categories of environmental protection expenditures used in the survey are listed in Text Box 5.3. In 1994, the surveyed industries included the following:

- Logging (SIC industry group 041);

1. Comparisons of the 1989 data with the 1994 data must be done with caution, since the scope of the two surveys was not the same.

- Mining (SIC industry groups 061, 062 and 063);
- Crude Petroleum and Natural Gas (SIC industry group 071);
- Food (SIC major group 10);
- Beverages (SIC major group 11);
- Pulp and Paper (SIC industry group 271);
- Primary Metals (SIC major group 29);
- Fabricated Metal Products (SIC major group 30);
- Transportation Equipment (SIC industry groups 321, 323, 324 and 325;
- Non-Metallic Mineral Products (SIC major group 35);
- Refined Petroleum and Coal Products (SIC major group 36);
- Chemicals and Chemical Products (SIC major group 37);
- Electric Power Systems and Gas Distribution Systems (SIC industry groups 491 and 492).

The selected manufacturing industries represented approximately one half of total manufacturing employment. To minimise response burden, establishments with less than 50 employees were not included in the survey. Some 3 500 units were surveyed.

In the 1995 EPES, the frame was extended to cover a sample of establishments in the rest of the manufacturing sector. The pipeline transportation industry was also included. To minimise response burden, the additional manufacturing industries (as well as the Transportation Equipment Industry, the Fabricated Metal Products Industry, and certain food industries) received a shorter version of the questionnaire. As a result, the 1995 survey is less detailed with respect to the additional manufacturing industries surveyed (and two of the manufacturing industries surveyed in 1994). Although the 1995 survey covered more industries, the number of establishments was reduced as a result of the introduction of sample surveying. Overall, 2 762 establishments were surveyed in 1995.

Expenditure data collected from the EPES are compiled by type of activity, by industry and province (region in 1994). In addition, information on EOP and CIP PAC capital expenditures are provided by environmental domain (air, surface water, soil and groundwater, noise and radiation). For those industries not covered by the survey, data from CRES are used to estimate PAC expenditures in 1994 and 1995.

Business operating expenditures

Operating expenditures on environmental protection are not easily reported by firms because of the difficulty in separating the environmental component out of total operating expenditures. The data that are available are mainly for expenditures on operating EOP facilities.

Some information on operating expenditures for EOP facilities and equipment is available for 1989 based on results from the *1989 Pollution Abatement and Control Survey*. A breakdown of PAC operating expenditures by expenditure category (labour, fuels and electricity, materials and supplies, services) can be provided at the national level and for major industrial divisions. Total operating expenditures are also available by type of pollutant.

More complete data on operating costs associated with environmental protection are available from the EPES. Operating expenditures are classified by the activities shown in Text Box 5.3. The own-account operation of waste or sewage treatment facilities included under EOP and CIP expenditures is distinguished from the purchases of waste and sewage treatment services. The latter are split between payments to private contractors and purchases of services from governments. Environmental fees, fines and licences represent payments to other economic sectors.

Government grants and subsidies received by the business sector for environmental purposes are included in the government sector account of the EPEA in accordance with the financing criterion. In order to avoid double counting between these two sectors, these transfers must be deducted from the business sector expenditures on environmental protection. This is not currently possible, as data on specific subsidies from governments or other sectors to the business sector are incomplete. Currently only partial federal and provincial government information on subsidies is available. Section 5.4 provides more details on this issue.

PAC research and development expenditures

The data from the EPES do not include expenditures on research and development (R&D) devoted to environmental protection. This information is available from another survey however. The *Survey of Research and Development in Canadian Industry* covers internal expenditures on PAC R&D made by firms for 1990, 1991, 1993 and 1995 (forthcoming). A question on the percentage of total R&D expenditures associated with pollution abatement and control has been included since the 1990 reference year. The survey covers both firms specialised in producing environmental goods and services, and the firms who demand these goods and services. In this regard it differs from the business surveys mentioned up to this point, which apply only to environment-protection demanding firms.

Other data sources

Additional data sources exist for certain industries. For example, the trade journal *Pulp and Paper Canada* publishes an annual report of PAC expenditures by a number of pulp and paper firms. Additionally, some companies publish an annual environmental performance report that contains information on their environmental protection expenditures. This information is used in the validation of data from the CRES and the EPES.

Administrative data are available from Revenue Canada's *Accelerated Capital Cost Allowance Program* for air and water pollution abatement equipment. These data are not appropriate for statistical purposes for several reasons: only companies in business prior to 1974 qualify for the program; companies tend not take advantage of these allowances in years of low or no profitability; and other tax provisions were more attractive for certain years of the program's existence. Since these data only address a minor portion of the demand for environmental protection activities, they have not been integrated into the EPEA.

5.4 Government account

Data on government expenditures for environmental protection are drawn from public accounts and a few other administrative sources through the Public Institutions Division of Statistics Canada, which collects the data. The data are classified by function (or purpose) following the *Financial Management System* (FMS), the reporting system for public sector revenue and expenditures. In the FMS classification, there are three functions that relate directly or indirectly to environmental protection: the “environment” function, the “natural resource conservation and industrial development” function, and the “parks” sub-function. Text Box 5.4 presents the classification of government environmental protection expenditures based on the FMS.

The measurement of environmental protection expenditures by governments is complicated by a problem similar to that encountered for the business sector: many government expenditures to protect the environment can have multiple purposes. For example, expenditures relating to resource management, agricultural development and energy programs can have both environmental protection and industrial development aspects. This problem is reflected in the FMS classification of expenditures on “natural resource conservation and industrial development.” How much of these expenditures should be considered environmental? The answer to this question would ideally be based on a programme-by-programme assessment of purpose. Despite the absence of such an evaluation, estimates of government expenditures on natural resource conservation and development are produced for the EPEA. They are kept separate from other government environmental protection expenditures however.[1]

5.4.1 Classification of government expenditures

The **environment** function of the FMS refers essentially to pollution abatement and control, but also includes an expenditure category called “water supply and distribution.” Expenditures associated with the supply and treatment of drinking water are classified to this category. These expenditures are excluded from the EPEA because they relate to the protection of human health rather than to environmental protection.

As alluded to above, only some of the components of the **natural resource conservation and industrial development** function of the FMS are considered environmental protection expenditures. Categories such as “tourism,” “trade and industrial development” and “water power” (control of damage due to floods and the installation of dams) are excluded from the EPEA. What remains is shown in Text Box 5.4 under the heading “natural resource conservation and development.” These expenditures comprise both those associated with the development of natural resources and those related to the conservation of these resources. Ideally, the EPEA would distinguish between these different types of activities, but this is not possible given current data sources.

Park expenditures are a component of the “Recreation and Culture” function of the FMS. They are considered environmental protection expenditures in the EPEA because of their close relationship with the protection of wildlife habitat. The expenditures included under this category comprise all those associated with implementing and maintaining national, provincial and municipal parks.[2]

In certain cases, government expenditures on environmental protection can be split among capital expenditures, current expenditures and transfer payments to other governments and sectors.

5.4.2 Data sources and methods

The mandates of different levels of government vary with regard to environmental protection. Local governments are mainly responsible for municipal sewage and solid waste management. Provincial/territorial and federal governments are more concerned with other pollution control activities, such as site clean-up and air pollution abatement, and services such as environmental administration and training. Expenditures on natural resource conservation and development are also almost entirely made by provincial/territorial and federal governments.

A summary of the data sources and availability for government environmental protection expenditures is presented in Annex 5.1. These data tend to be characterised by:

- differing levels of detail over time and by level of government;
- problems in eliminating double counting resulting from insufficient information on transfers between governments;
- classification difficulties arising from the multi-purpose nature of some expenditures;

1. Including these expenditures in the EPEA leads to overestimation of the size of expenditures and range of activities involved in government environmental protection.

2. These expenditures may also overestimate the size of government environmental protection expenditures, since some park expenditures may relate more to recreation than to environmental protection.

Text Box 5.4
FMS Classification of Government Environmental Protection Expenditures

1. Pollution abatement and control (part of the "environment" function)

- sewage collection and disposal: expenditures on the construction and maintenance of sewage removal and treatment facilities (including sanitary sewers and combined sanitary-storm sewers); expenditures related to inspection and cleaning of sewers; subsidies related to assistance and research in this area
- waste collection and disposal: expenditures on construction and maintenance of waste collection and disposal facilities (including landfill sites, incineration, recycling and landfill site cleanup); expenditures on managing waste collection and disposal programs
- pollution control: all expenditures to prevent or reduce air, water, soil or groundwater pollution
- other environmental services: expenditures for such services as general administration of environment ministries, environmental education, environmental assessments, contributions to environmental agencies

2. Natural resource conservation and development (part of the "natural resource conservation and industrial development" function)

- agriculture: expenditures for research, price stabilisation, soil conservation and protection against soil erosion, farm subsidies, and drainage
- fish and game: expenditures for research and management of fish and wildlife, including aquaculture, and wildlife habitat protection
- forests: expenditures for research, pest and fire control, construction of logging roads and reforestation
- mines, oil and gas: expenditures related to research, exploitation and conservation of mineral resources
- other: expenditures related to the management of Crown land, energy conservation, subsidies to conservation agencies for energy-related R&D

3. Parks

- expenditures on park planning and development, park commissions, park design and implementation, visitors services, provincial park operations, and park construction and development

- reporting delays caused by recourse to administrative data in lieu of direct surveys; and
- inconsistent reporting periods.

Pollution abatement and control expenditures

Consolidated government expenditures - One of the main challenges in producing a government account on environmental protection expenditures is obtaining consolidated data.[1] The required information on intergovernmental transfer payments is not available for all three levels of government.

Despite shortcomings in the data, an annual time-series of consolidated total government expenditures for PAC is available from 1970/71 to 1994/95. These data, derived from the public accounts,[2] show the total financial contribution of the government sector to PAC, include payments to the private sector for PAC goods and services and other PAC-related transfer payments. A breakdown of expenditures by PAC activity (see Text Box 5.4) is available. Estimates of consolidated provincial/local government expenditures by PAC activity are available both at the national and provincial/territorial levels, although these data may include transfer payments from local to provincial governments.

In addition to total government expenditures for PAC, consolidated government capital and repair expenditures for PAC are available from 1985 to 1995 based on the CRES. It must be noted that CRES and public accounts data are not always compatible because of different collection and estimation methods.

Non-consolidated government expenditures - The level of detail available for non-consolidated government PAC expenditures, as well as the years for which the data are available, vary according to the level of government. This is mainly because different methods are used in collecting the data (see Annex 5.1 for details).

Federal public accounts provide information on total federal government PAC expenditures by type of activity from 1970/71 to 1995/96. They do not provide a breakdown between current and capital PAC expenditures at that level of detail. Total capital and repair expenditure data on PAC are available for the federal government from 1985 to 1995, based on the CRES.

Total provincial/territorial government expenditures on PAC are available by province/territory for each category of PAC

1. Consolidated data net out inter-governmental transfers to show total, unduplicated public spending on environmental expenditure.
2. The public accounts use a classification that is similar to that of the FMS.

activity from 1970/71 to 1994/95, again based on public accounts data. In addition, total PAC expenditures are available for more recent years (1988/89 to 1994/95) for the following categories:

- current expenditures on goods and services;
- capital expenditures;
- expenditures on non-specified goods and services;
- transfers to individuals;
- transfers to businesses;
- transfers to local governments and to other levels of government;
- interest payments on public debt;
- expenditure reconciliation and integration (expenditures not specified above);
- direct and indirect taxes;
- revenues/receipts offset against expenditures.

Total local government expenditures are available by type of PAC activity and province/territory beginning in 1965/66. The split between capital and current expenditures is available beginning in 1983/84. The data are net of transfer payments to other local governments, but not necessarily net of transfers to other governments.

It must be noted that CRES and Public Institutions Division's capital expenditure data are not always compatible at the aggregate level. This is due to differences in concepts, estimation methods and (primarily) definitions of what is measured.

Natural resource conservation and development expenditures

Non-consolidated data on natural resource conservation and development expenditures made by governments (based on public accounts) generally follow the model just outlined for PAC expenditures (see Annex 5.1 for details). There is one major difference however. Data on capital expenditures relating to natural resource conservation are not available from the CRES. Consequently no data on capital expenditures made by the federal government are available for this function.

Park expenditures

Data on park expenditures are available for provincial/territorial governments beginning in 1988/89. The data are available by the same economic categories listed above for PAC expenditures. Federal government data on parks are not readily available.

5.5 Household account

The EPEA account for the household sector[1] exists in concept only at this time; data development is still in the planning stage. Although no data have yet been collected, the accounting concepts for this account are well formulated.

Household environmental protection expenditures include payments made to control and abate pollutants emitted to soils, water and air, as well as household spending to manage the solid wastes they produce. The associated expenditure levels are likely to be modest in comparison with those of other sectors. At least, this has been the case in other countries that have included household expenditures in their environmental protection accounts.

As with the other components of the EPEA, the household account uses the regulation/convention criterion to define environmental protection expenditures. Relatively few household expenditures actually meet this criterion however. Expenditures on solid waste management and sewage treatment are typically the only household expenditures that fall under this criterion.

Households make a number of outlays that might be considered, at least in part, environmental protection expenditures but that are not required by legislation. An example is improvements made to the efficiency of home space and water heating systems. The resulting reduction in energy consumption yields cost savings for the household, as well as having a positive environmental impact. The household's motivation for undertaking such improvements may be purely financial, or it may be a combination of the desire to save money and to protect the environment. Despite the possibility of an environmental motivation, since these expenditures are not required by law they do not meet the criterion for inclusion in the EPEA as environmental protection expenditures.

Household environmental protection expenditures are classified according to environmental domain following the European classification of environmental protection expenditures (Text Box 5.2).

5.5.1 Elements of the account

Air pollution control

The first element of the household account is expenditure to reduce the emissions of air pollutants from fuel combustion and other sources. Motor vehicles are the primary regulated source of household air pollution. Legislation requires that motor vehicles be fitted with pollution control devices in the form of catalytic converters. Vehicles are also equipped with control systems that prevent fuel vapours from being

1. This sector is also referred to as the "personal sector." In addition to private households, it is defined to include private non-profit organisations such as religious and welfare organisations, other voluntary groups, private clubs and labour unions.

emitted to the atmosphere. Both devices add to the cost of vehicle and the resulting costs imposed on households are included in the household account.

Households also release pollutants to the air from water and space heating equipment. The heating systems in use today are not required by regulation to have specific pollution control devices however. While furnace and fireplace chimneys, for example, are subject to design standards, these reflect considerations for householder safety rather than environment considerations. Thus, there is no household environmental expenditure associated with heating systems.

Solid waste management

Expenditure on solid waste management is the second element of the household account. Governments provide the bulk of this service to households and the associated expenditures are, as already mentioned, included in the government account. To avoid double counting, these expenditures are not recorded again in the household account.

In some locations, and for certain dwelling types (primarily large apartment buildings), government waste management services are unavailable. In these instances, private businesses may collect household waste and deal with its disposal on a fee-for-service basis. The expenditures made by households for these services are included in the household account. The removal and disposal of certain household waste items are not covered by municipalities as part of normal waste management services. These items vary by location, but often include construction wastes, yard wastes, wood, white goods and old motor vehicles. Again, private businesses may collect these items and deal with their disposal on a fee-for-service basis; any resulting expenditures are also recorded in the household account.

Also included under the solid waste category of the household account are the expenditures households are required to make in order to receive waste management services, whether government or private. These include, for example, expenditures on garbage cans, wheelie bins and plastic garbage bags.

Regulations in many municipalities prevent the burning of leaves and other waste products on household property. Payments to manage these wastes are recorded as household environment expenditure if the service that replaces the burning is provided for a fee by the business sector. If municipal programs (leaf recycling for example) are used instead, the expenditure is already recorded for the government sector and is not recorded again for households.

Wastewater treatment

The third element of the household account is expenditure on household sewage treatment. Again, governments provide the bulk of these services to households. Household expenditures on sewage treatment are included in the account only in cases when government services are not available. In the case of self-supplied sewage treatment, the initial cost of septic systems and the costs to maintain them are included as environmental expenditure.

Noise abatement

The fourth element of the household account is expenditure to control noise. The major expenditure in this category is for mufflers fitted to the exhaust systems of motor vehicles. Noise laws prevent the operation of motor vehicles without suitable noise suppression devices and require that faulty devices be repaired promptly.

Other environmental protection expenditures

The final element of the account goes beyond the regulation/convention criterion to include voluntary household donations to environmental organisations, which represent transfer payments within the broader household (or personal) sector. Also included are expenditures for environment-related entertainment; camping trips and bird feeders for example.

5.6 Data gaps

A general impediment to the production of the EPEA is the time-lag in data availability. Typically, environmental protection expenditure data are 2-3 years out of date when they become available. Improving the timeliness of the data is an important goal for the future.

Beyond this general shortcoming, each of the three accounts of the EPEA has its own unique data gaps.

5.6.1 Business sector

A major data gap for the business sector is the lack of historical information on operating expenditures for environmental protection. Currently, few years of data are available –1989, 1994 and 1995. Also, it is not possible to split the 1994 and 1995 data between expenditures on primary inputs and intermediate consumption associated with environmental protection activities.

Capital costs, that is depreciation and holding costs on the capital stock employed in environmental protection, may form a significant part of total annual environmental protection costs. In the Netherlands, for instance, capital costs have been estimated at 50 percent of annual operating costs (Eurostat, 1994b). However, no historic data on the capital costs of equipment used specifically for environmental protection purposes are available in Canada. These costs could be calculated given a time-series of investment data and assumptions about the depreciation rate of the environmental equipment. Use of a replacement cost valuation for capital in this calculation would be in accordance with capital cost calculations elsewhere in the CSNA.

As mentioned earlier (page 111), any revenues or savings generated from the sale of by-products from environmental protection activities (sulphur scrubbed from the stacks of coal-burning industrial facilities for example) should be subtracted from the associated expenditures. The information required to allow this has been collected only for 1989. Evidence from the *1989 Survey of Pollution Abatement and Control Expenditures* (Statistics Canada, 1992) suggests that revenues from the sale of by-products are relatively small in comparison to PAC operating costs, about 10 percent.

5.6.2 Government sector

Government PAC expenditure data are not very detailed with respect to category of activity undertaken. Other than waste and sewage management, no activity-specific data are available on the PAC activities of different levels of government.

Expenditures for water supply and distribution are excluded from the EPEA. However, it appears that some provincial government data on sewage disposal and treatment may be included in the “water supply and distribution” category of the FMS. The data included in the EPEA for these governments therefore underestimate the value of their sewage treatment expenditures. Work is required to estimate the share of reported water supply expenditures that actually represents sewage treatment.

Data on natural resource conservation and development expenditures do not provide a split between environmental protection expenditures and other expenditures. This is a particular concern for the federal and provincial/territorial governments. Further investigation of the programs and budgets of the departments involved is required to determine if these expenditures can be separated.

Detail on transfer payments between governments are currently unavailable for the local governments. This complicates the estimation of consolidated government expenditures by environmental protection activity.

5.6.3 Household sector

As noted above, data development for this sector is still in the planning stage. The approach that will be used to fill this major data gap is outlined below in Section 5.7.1.

5.7 Future directions

The development of the EPEA to date constitutes a major step forward in our understanding of environmental protection expenditures and their contribution to economic activity in Canada. Nevertheless, substantial work remains to expand the scope and improve the quality of the estimates, and to reconcile data from various sources into a coherent set of accounts. Projects with these objectives are already under way.

5.7.1 Sectoral accounts

Business sector

Since environmental protection expenditure data in the business sector are derived from a variety of sources that employ different scopes and methods, data reconciliation is key to producing an integrated EPEA. This will be the subject of much of the future work on this account. CRES data will be used to compliment the data from the EPES, allowing PAC capital expenditures for all industries to be estimated.

The 1996 EPES will provide an enhanced coverage of the whole manufacturing sector. Results will be available in the summer of 1998.

A new question has been introduced to the *Survey of Research and Development in Canadian Industry.* Starting in 1996, this survey will request information about expenditures on R&D with significant environmental benefits, whether or not the research is undertaken for environmental purposes.

Government sector

The consolidation of expenditure data by type of environmental protection activity and the reconciliation of capital expenditure data from different sources will be the focus of much future work on the government account. Shortening the time required to compile the data will also be the object of future attention.

Work is currently under way to fill some of the most important data gaps. This foremost involves finding means to estimate government transfers. As well, information for local governments will be improved to allow measurement of the proportion of their waste management expenditures made for the provision of services by private contractors. This may be achieved by introducing a question on the *Local Government - Current Revenue and Expenditure Survey*, or by obtaining information directly from the Financial Report of the Department of Municipal Affairs of each province/territory.

Other tasks will include estimating the sewage treatment component of certain expenditures currently classified under water supply and investigating additional public accounts information on natural resource conservation and development and parks activities. A reconciliation of PAC capital expenditure data from the public accounts and the CRES will also be made.

Household sector

As noted above, data for this account remain to be developed. Thus, the first order of business will be the identification of suitable data sources and methods.

The expenditures on air pollution control devices on new vehicles (catalytic converters and evaporative-emission control devices) will be measured by multiplying the per-unit price by the number of new cars purchased by households. On-going costs for operating these devices are virtually nil according to U.S. estimates (Rutledge and Leonard, 1992).

(Expenditures on pollution control devices on vehicles purchased by other than the household sector will also be calculated. To the extent possible, these values will be included with the environmental protection expenditures of the purchasing sector.)

Estimates of expenditures on garbage storage and collection equipment will be developed from data in the *Family Expenditure Survey*, as well as from industrial surveys.

The approximate cost of a private septic system can be identified from contractors who install these systems. The number of installations made per year is available from local governments as part of their permitting system. Statistics Canada's household surveys may also provide additional material.

With respect to mufflers on motor vehicles, similar methods to those used to calculate expenditures on pollution control devices will be applied. New vehicle sales and the unit cost of muffler systems are known. Per-unit prices of replacement mufflers are readily available, as are the labour costs to install them. (Again, expenditures on vehicle noise-control systems made by other sectors will be estimated as well.)

Additional work remains to be done to define environmental protection expenditures in the broader personal sector. Areas of interest include payments by households to environmental and wildlife organisations, and the environmental protection expenditures of non-profit organisations.

Sectoral consolidation

Ultimately, the accounts for the three sectors will be consolidated to present an overall picture of environmental protection expenditures in the economy. This will require improving information on transfer payments between sectors in order to eliminate double-counting.

5.7.2 Measuring the Environment Industry

As a participating agency in the *Environment Industry Strategy* launched in 1996 by Environment Canada and Industry Canada, Statistics Canada has the task of producing a national statistical database on and for the Environment Industry.[1] This database, and the work that will follow from it, may eventually allow Statistics Canada to assess both the supply of and demand for environmental protection activities in an integrated accounting framework.[2]

Such an account would be a useful tool for assessing the economic effects of the provision of environmental protection activities in terms of revenue, employment, export potential and other parameters. It would, for example, provide answers to questions that are currently the subject of much interest:

- What environmental protection activities are undertaken in the economy?
- What is the sectoral demand for these activities?
- Who are the suppliers of environmental goods and services?
- What is the percentage of GDP represented by the provision of environmental protection activities?
- What are the environmental uses of goods and services as opposed to their non-environmental uses?

The Input-Output Accounts provide a framework that could be used to integrate both the supply and demand for environmental protection. Indeed, this framework is already in use for integrated environmental protection accounts in some other countries. The conventional Input-Output Accounts do not classify production and consumption according to purpose however, so environmental protection activities are not presented explicitly within the accounts. In order to show these activities explicitly, it is necessary to separate the environmental and non-environmental components of all economic activity measured in the accounts. This task, while feasible in theory, requires information that does not exist currently in Canada. New surveys created to identify the producers of environmental goods and services and measure their output promise to provide the required information in the not-too-distant future.

New survey work

The *1995 Environment Industry Survey* will provide information on sales of environmental goods and services (including construction) both domestically and to export markets, and on capital and operating expenditures and employment in firms producing these commodities. Firms undertaking environmental protection as their main activity, as well as those for which this is a secondary activity, are included in this survey. Results will be available in the fall of 1997.

Results from the *1994 Waste Management Industry Survey* are currently available. They include information on employment and revenues from the sale of the following waste management services: waste collection and transportation; preparing recyclable materials for further processing; operating non-hazardous waste disposal facilities; managing hazardous wastes; and "other services." Data on capital and operating expenses are available from this survey. Results from the 1995 survey will be published in the fall of 1997.

The *Survey of Consulting Engineers,* the *Survey of Scientific and Technical Services* and the *Survey of Management Consultants* provide information on the percentage of revenue for these firms associated with the provision of environ-

1. The Environment Industry is defined by Statistics Canada as all companies operating in Canada that are involved in whole or in part in the production of environmental products, the provision of environmental services and the undertaking of environment-related construction activities.
2. Annex 5.2 presents European and U.S. approaches to integrating demand and supply aspects of environmental protection activities.

mental services. Data for 1991 and 1994 will be available in the summer of 1997.

In addition to these business surveys, the *Local Government Waste Management Survey* provides data on local government revenues from waste management services not funded from tax revenues (provision of waste management services, sale of recyclable materials, “other”); and related current and capital expenditures (collection and transport, disposal facilities, recycling, “other”). Data from this survey are available for 1993 and 1994.

Information from the two waste management surveys will be integrated with data on waste management expenditures from the Financial Management System, from the EPES and from the CRES. Information from the *Environment Industry Survey,* the *Survey of Consulting Engineers,* the *Survey of Management Consultants* and the *Survey of Scientific and Technical Services* will be integrated with data from the EPES.

5.7.3 Measuring the effectiveness of environmental protection expenditures

Canadians should be apprised of the magnitude of environmental protection expenditures so that they can assess their effectiveness in terms of reduced environmental damage. One means of doing so would be to link environmental expenditure data from the EPEA with data on waste output from the Material and Energy Flow Accounts (Chapter 4). Ideally, integration of these accounts would show how expenditures on environmental protection impact waste production over time.

At the moment it is not possible to collect environmental protection expenditure information at the level of detail necessary to match it with specific changes in waste production. An integrated account showing changes in levels of, for example, sulphur dioxide (SO_2) emissions as a result of environmental protection expenditures cannot be established without data specific to expenditures on reducing SO_2 emissions. Nonetheless, a framework for linking waste emission data, the expenditures made to reduce emissions and the economic and environmental impacts of emission reductions will be investigated for future development.

Annex 5.1
Data Sources for the EPEA

Data requirement	Data source	Comment
Capital expenditures on pollution abatement and control (PAC), **business sector**	*Capital and Repairs Expenditure Survey* (CRES), 1985-1995 *1994, 1995 Environmental Protection Expenditure Survey* (EPES) *1989 Pollution Abatement and Control Survey* (PACS)	Detail by type of PAC asset from CRES is not available by industry because of data confidentiality. The 1994 EPES covers 9 manufacturing industries and 4 primary industries (Logging; Mining; Crude Oil and Natural Gas, Electrical Power and Gas Distribution Industries; Food; Beverages; Pulp and Paper; Primary Metals; Fabricated Metal Products; Transportation Equipment [Aircraft and Aircraft Parts; Motor Vehicles; Trucks, Bus Bodies and Trailers; Motor Vehicle Parts and Accessories]; Non-Metallic Mineral Products; Refined Petroleum and Coal Products; Chemicals and Chemical Products. In 1995, a sample of the rest of the manufacturing sector was drawn and the pipeline transportation industry was surveyed. The EPES provides more detailed information on PAC expenditures than the CRES (EOP vs. CIP expenditures and a breakdown by medium). The scope of the two surveys is not the same. A reconciliation of the data is necessary. The PACS covers establishments reporting PAC expenditures in CRES and provides information only on specific EOP PAC expenditures for 1989. These surveys exclude R&D expenditure data.
Capital expenditures on other environmental protection activities, **business sector**	*Environmental Protection Expenditure Survey* (EPES)	See above.
Operating expenditures on environmental protection, **business sector**	*Environmental Protection Expenditure Survey* (EPES) *1989 Pollution Abatement and Control Survey* (PACS)	The EPES covers a broad range of activities for selected industries. The PACS covers establishments reporting PAC expenditures in CRES and provides information only on specific EOP PAC expenditures for 1989. The two surveys do not represent the same universe.
R&D expenditures on PAC, **business sector** and institutions serving industry	*Research and Development in Canadian Industry,* 1990, 1991 and 1993	The survey covers total internal expenditures on PAC R&D. No breakdown between capital and operating expenditures is available.
Total consolidated **government** expenditures on PAC Total consolidated **government** expenditures on natural resource conservation and development	Public accounts, 1970/71-1994/95 *Local Government - Current Revenue and Expenditure Survey* *Local Government - Capital Expenditure Survey* Financial report of the Department of Municipal Affairs of each province/territory (local governments)	Local government data may contain some transfer payments from local governments to the federal or provincial governments.
Total **government** expenditures on PAC, by level of government (non consolidated) Total **government** expenditures on natural resource conservation and development, by level of government (non consolidated)	Public accounts (federal government), 1970/71-1995/96 Public accounts (provincial/territorial governments), 1970/71-1994/95 *Local Government - Current Revenue and Expenditure Survey* *Local Government - Capital Expenditure Survey* Financial report of the Department of Municipal Affairs of each province/territory (local governments)	Breakdowns by type of PAC activity and by type of natural resource conservation and development activity are available for the following periods: Federal: 1970/71-1995/96 Provincial/territorial: 1970/71-1994/95 Local: 1965/66-1994/95

Data requirement	Data source	Comment
Capital expenditures on PAC, **government sector**	*Capital and Repairs Expenditure Survey* (CRES), 1985-1995 Public accounts (provincial/territorial governments), 1988/88-1994/95 Financial report of the Department of Municipal Affairs of each province/territory and *Local Government - Capital Expenditure Survey*, 1983/84-1994/95 (local governments)	With respect to capital expenditures by type of PAC asset, CRES does not necessarily provide the PAC asset breakdown by level of government for confidentiality reasons. Provincial/territorial government data and local government data are available by province/territory. Available tables show data from CRES only.
Capital expenditures on natural resource conservation and development, **government sector**	Public accounts (provincial/territorial governments), 1988/89-1994/95 Financial report of the Department of Municipal Affairs of each province/territory and *Local Government - Capital Expenditure Survey*, 1983/84-1994/95 (local governments)	No capital expenditure data are available for the federal government. Provincial/territorial government data and local government data are available by province/territory.
Current expenditures on PAC, **government sector**	Public accounts (provincial/territorial governments), 1988/89-1994/95 Financial report of the Department of Municipal Affairs of each province/territory and *Local Government - Current Revenue and Expenditure Survey*, 1983/84-1994/95 (local governments)	No PAC current expenditure data available for the federal government. Provincial/territorial government data and local government data are available by province/territory.
Transfer payments between **governments** and between **governments and other sectors**	Public accounts (federal government), 1970/71-1995/96 Public accounts (provincial/territorial governments), 1988/89-1994/95	
Household expenditures on air pollution control devices	Number of vehicles purchased and unit prices for devices.	To be developed.
Household waste removal on a fee-for-service basis **Household** expenditures on garbage storage and collection equipment	*1994 Private Waste Management Industry Survey* *Family Expenditure Survey* and industrial surveys Occasional services only; other sources	To be developed.
Household expenditures on septic systems	Data on cost of private systems available from contractors. Data on number of installations available from local government permits. *Family Expenditure Survey*	To be developed.
Household expenditures on mufflers	For new vehicles: number of vehicles sold plus data on per-unit costs. For replacements: value of replacement mufflers, including labour costs.	To be developed.
Household expenditures on wildlife and habitat protection	*Survey of the Importance of Wildlife to Canadians* Voluntary donations to non-profit organisations (intrasectoral transfer payments). Expenditures to protect wildlife, visit parks, etc.	To be developed.

Annex 5.2
EPEA frameworks in Europe and the United States

SERIEE framework

SERIEE is the acronym for *Système européen de rassemblement de l'information économique sur l'environnement*,[1] the environmental protection accounting framework of the European Community (Eurostat, 1994a and 1994b). The system's main objectives are:

- evaluation of the costs of environmental protection activities;
- evaluation of how these costs are borne; and
- identification of the economic activities that result from environmental protection.

The environmental protection accounting framework of SERIEE is composed of three central tables addressing each the system's three main objectives. Table A values the different components of national expenditures for environmental protection, by users and beneficiaries; Table B presents the output of environmental protection activities; Table C describes the financing of environmental protection expenditures.

Environmental protection activities are classified according to producer in SERIEE (and by the United States). The SERIEE classification is shown in Text Box A5.1. Table B of SERIEE describes environmental protection output of each type of producer: primary, secondary and internal. Differentiating between producers is necessary in order to understand the nature of the demand for and supply of environmental protection activities.

Beyond the environmental protection expenditure account, SERIEE will eventually include an account describing the use and management of resources. This second account will identify and measure the management of water, forest, soil and energy resources, as well as recycling and material recovery activities not already covered in the protection expenditure account.

Text Box A5.1
SERIEE Classification of Environmental Protection Activities by Producer

Primary (or external) activities are environmental protection activities carried out by producers whose principal interest is environmental protection; for example, waste management services provided by a private contractor at a market price.

Secondary activities are environmental protection activities carried out by producers for whom environmental protection is not the main production activity; transportation of hazardous waste by a truck transportation company for example. For such activities, only the total value of output is available, as their use for environmental protection cannot be distinguished from other uses.

Internal (or ancillary) activities are environmental protection activities carried out by producers on own-account in order to limit the environmental impacts of their activities; for example, treatment of liquid waste effluents from a pulp and paper mill. Typically, these activities are carried out by businesses in "polluting" industries. The associated intermediate and capital outlays have to be identified through special surveys because of the ambiguity of these activities.

In addition, there are **connected and adapted products**. These are products whose use serves an environmental-protection purpose. **Connected products** directly serve environmental protection purposes without being explicitly "environmental" goods; catalytic converters and septic tanks for example. **Adapted products**, or "green products" as they are sometimes called, are those that are less polluting at the time of consumption or disposal compared with equivalent "normal" products, but that are more costly. In such cases, the additional cost above that of an equivalent, less benign product is considered environmental protection expenditure.

U.S. framework

The U.S. Environmental Protection Agency (EPA) has chosen to develop an input-output framework to identify and to assess the "environmental protection industry." The U.S. input-output tables for the period 1977-1991 were adjusted to isolate environmental protection activities from other economic activities. The production of goods and services for the purpose of compliance with environmental regulations, as well as the demand for these goods and services, are shown in the U.S. framework (Vaughn Nestor and Pasurka, 1995). Survey data, engineering studies and administrative data are used to disaggregate environmental protection activities. The EPA then uses the input-output tables to produce indicators of the importance of environmental protection activities in the overall economy. These indicators include, for example, the contribution of environmental protection activities to GNP, and the direct and indirect employment derived from these activities.

Such an elaborate framework requires detailed data, not only on final demand for environmental protection activities, but also on intermediate consumption associated with the provision of environmental protection activities.

1. *European System for the Collection of Economic Information on the Environment.*

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Further Reading

This list is intended for those readers wishing to delve further into the topics covered in this volume. Cited works are organised according to the following categories:

- general reference works on the environment;
- works on the economic theory of the environment and natural resources;
- works on environmental and resource accounting;
- works on valuation of the environment and natural resources;
- general works on natural resources;
- current and historical publications of the *Canadian System of National Accounts*; and
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Glossary

This glossary provides definitions for terms related to the environmental and resource accounts presented in this volume. Entries are structured according to the following rules.

- Definitions begin with the term to be defined presented in **bold text**.
- Where terms defined elsewhere in the glossary form part of definition, these are presented in the definition in ***bold italicised text***.
- Terms that commonly appear in abbreviated form in this volume are presented with the abbreviation in (parentheses); the abbreviations themselves are included in separate entries in the glossary with pointers to the unabbreviated term.
- Synonyms and/or terms related to the defined term, where these exist, are listed at the end of definitions, preceded by the words "See also."

Abater criterion: Criterion used to classify ***environmental protection expenditures*** by which such expenditures are attributed to the sector in which they are made, regardless of which sector originally finances the outlay. Thus, expenditures on waste management by governments are classified to the government sector under the abater criterion, although they are originally financed by households through property taxes.

See also: ***financing criterion***.

Agricultural ecumene: An area defined from the *Census of Agriculture* delimiting the portion of Canada in which agricultural activity occurs. It is used in mapping of agricultural data to restrict the information to actual agricultural areas.

See also: ***ecumene***.

Business capital expenditures: Outlays made by businesses for procuring, constructing and installing new infrastructure, machinery and equipment, whether for replacement of worn assets, as additions to existing assets or for lease or rent to others. Also included are all capitalized costs associated with demolition, planning and design (such as engineering and construction fees), the value of mineral exploration and development costs, and any costs associated with the purchase of land that are neither amortized nor depreciated. Business capital expenditures are reported gross of any grants or subsidies received.

See also: ***capital expenditures***; ***government capital expenditures***; ***operating expenditures***.

Business sector: All economic units that produce goods and services for sale at a price that is intended to cover the full cost of production, including a profit for the owners. These units include corporations, unincorporated business enterprises, independent professional practitioners and government business enterprises.

CanFI91: Acronym for "Canadian Forest Inventory 1991," a principal data source for the Timber Asset Accounts.

CIP: Acronym for ***change-in-process***, used in reference to ***environmental protection expenditures***.

CLI: Acronym for "Canada Land Inventory" a principal data source for the Land Account.

CLUMP: Acronym for "Canada Land Use Monitoring Program."

CNBSA: Acronym for ***Canadian National Balance Sheet Accounts***.

CORINE: Acronym for "Coordination of Information on the Environment," used in reference to the land accounting system of the European Union.

CRES: Acronym for "Capital and Repairs Expenditure Survey," a principal data source for the Environmental Protection Expenditure Accounts.

CSERA: Acronym for Canadian System of Environmental and Resource Accounts.

CSNA - Acronym for ***Canadian System of National Accounts***.

Canadian National Balance Sheet Accounts (CNBSA): One of the set of accounts comprising the ***Canadian System of National Accounts***. The CNBSA is a statement, drawn up for the end of the calendar year, of the values of financial and non-financial assets owned by Canadian economic agents and of the net financial liabilities against Canadians by the economic agents of foreign countries. The CNBSA is drawn up for the four broad sectors of the economy (businesses, persons, governments and non-residents), showing the economic status of each sector; that is, the financial and tangible assets at its disposal.

Canadian System of National Accounts (CSNA): A set of integrated accounts portraying the most important macroeconomic information required for the fiscal management of the Canadian economy. In its broad outline, the CSNA bears a close relationship to the international ***System of National Accounts 1993***.

Capital expenditures: Expenditures by business or government on machinery, equipment, buildings and other goods that have useful lives of more than one year.

Census division: A geographic unit that is intermediate in size between a ***census subdivision*** and a province. Census divisions are used primarily as spatial units for collecting and disseminating information from the *Census of Population*. In 1991, there were 290 census divisions in Canada.

See also: ***census subdivision***; ***enumeration area***.

Census subdivision: A geographic unit generally describing a municipality or equivalent (Indian reservations for example) used for collecting and disseminating information from the *Census of Population*. There were 6006 census subdivision in 1991.

See also: ***census division***; ***enumeration area***.

Change-in-process (CIP): Term for a new or significantly modified production process used in reference to ***environmental protection expenditures***. Examples of CIP expenditures include process modifications to allow for material substitution or the reuse of water in a production system.

Synonym: integrated process.

See also: ***end-of-pipe***.

Consolidated census subdivision: A grouping of small ***census subdivisions*** within a containing census subdivision created for convenience and ease of geographic referencing. Consolidated census subdivisions are used primarily for the dissemination of information from the *Census of Agriculture*.

See also: ***census division***; ***census subdivision***; ***enumeration area***.

Convention: See ***environmental convention***.

Cost of produced capital: The cost to the owner for the use of ***produced capital*** in a business activity. In theory, this cost can be calculated as $rK + \delta$, where δ is the ***rate of depreciation*** of the produced capital stock and rK is the ***return to produced capital***.

Current expenditures: See ***operating expenditures***.

DCW: Acronym for “Digital Chart of the World,” an electronic map of the earth’s surface (Environmental Systems Research Incorporated, 1993).

Defensive expenditures: Expenditures undertaken by any economic agent for the purpose of defence against a deterioration of the environment. They include expenditures made with the intention of offsetting, remedying or preventing environmental degradation.

Direct-use value: The value of a ***natural resource asset*** associated with its use in economic activity; for example, as a source of raw material. The value of recreation and other non-consumptive uses of the environment, such as aesthetic appreciation, are included in direct-use value. Some direct-use values are part of the ***market value*** of natural resource assets (resource extraction value for example). Others are part of ***non-market value*** (the value of aesthetic appreciation for example).

See also: ***indirect-use value***; ***market value***; ***non-market value***; ***non-use value***.

Discount rate: The rate used to discount future income in the ***present value method*** of valuing ***natural resource assets***. The discount rate expresses the degree to which an economic agent prefers income today rather than in the future. This time preference will vary depending on the agent in question. In general, individuals and businesses have higher rates of time preference than governments. That is, individuals and businesses tend to demand a quicker return from an investment than governments. Higher rates of time preference translate into higher discount rates. In addition to time preference, discount rates can also reflect risks associated with the future returns expected from an investment.

Durable good waste: ***Waste*** produced when long-lived goods are discarded. Includes, among others, wastes from buildings and other built infrastructure, machinery and equipment (commercial and household), vehicles and furnishings.

EA: Acronym for ***enumeration area***.

EIS: Acronym for “Environmental Information System,” a ***GIS***-based information system of Statistics Canada.

EOP: Acronym for ***end-of-pipe***, used in reference to ***environmental protection expenditures***.

EPEA: Acronym for “Environmental Protection Expenditure Accounts.”

EPES: Acronym for “Environmental Protection Expenditure Survey,” a principal data source for the Environmental Protection Expenditure Accounts.

Ecodistrict: A sub-component of an ***ecoregion*** characterized by distinctive assemblages of relief, geology, landforms and soils, vegetation, water, fauna, and land-use. There are 5 395 ecodistricts in Canada.

See also: ***ecozone***; ***ecoregion***.

Economic activity: As defined in the ***Canadian System of National Accounts***, economic activity comprises all activities involved in producing goods and services for sale in the marketplace. This definition is extended in the ***CSERA*** to include all activities involved in commodity production and/or consumption, whether of commodities traded in the market, or of commodities produced and consumed by the same economic agent with no associated transaction.

Economic rent: See ***resource rent***.

Economically recoverable reserves: Reserves of subsoil assets that can be recovered under current technological and economic conditions.

Economically sustainable development: See ***Sustainable development***.

See also: ***natural resource assets***; ***reserves***.

Economy-environment indicator: A time-series measure summarizing an aspect of the relationship between economic activity and the environment.

Ecoregion: A sub-component of an ***ecozone*** characterized by distinctive regional factors, including climate, physiography, vegetation, soil, water, fauna and land-use. There are 217 ecoregions in Canada.

See also: ***ecozone***; ***ecodistrict***.

Ecosystem: A biological community of interacting organisms and their physical environment.

Ecozone: A large area of the earth's surface delineated by distinctive sets of non-living and living resources that are ecologically related. Each zone can be viewed as a discrete system resulting from the interplay of the geologic, geographic, soil, vegetative, climatic, wildlife, aquatic and human factors which may be present in the region. There are 15 ecozones in Canada.

See also: ***ecodistrict***, ***ecoregion***.

Ecumene: A term derived from the Greek used in reference to the permanently settled portion of a country, or "inhabited land." The concept is employed in thematic mapping to ensure that the spatial representation of data is limited to a particular area, such as agricultural land.

See also: ***agricultural ecumene***.

End-of-pipe (EOP): Term for a facility or equipment added to a production process (and not an integral part of the process) with the sole intent of reducing and/or neutralizing the ***waste*** associated with that process. EOP is used in reference to ***environmental protection expenditures*** to describe expenditures with the sole purpose of protecting the environment.

See also: ***change-in-process***.

Enumeration area (EA): A geographic unit describing the area canvassed by one representative, or enumerator, for the *Census of Population*. The number of dwellings in an enumeration area varies between 375 in urban areas and 125 in rural areas. Enumeration area boundaries do not cross those of any of the other areas defined for the Census.

See also: ***census division***; ***census subdivision.***

"Environment industry": All companies operating in Canada that are involved in whole or in part in the production of environmental products, the provision of environmental services and the undertaking of environment-related construction activities. These companies produce goods and services that are used, or can potentially be used, to measure, prevent, limit or correct damage (both natural and man-made) to water, air and soil. The industry also includes companies that produce technologies and related components that minimise pollution, material and energy use.

Environmental convention: Any formal, multi-party commitment among businesses, or between government and business, to meet specific environmental targets. Examples include the Canada-United States *Air Quality Agreement*, the *National Packaging Protocol*, and the *Responsible Care* program adopted by the Canadian Chemical Producers Association.

See also: ***environmental regulation***; ***environmental protection expenditures***.

Environmental protection expenditures: ***Current*** and ***capital expenditures*** made to comply with, or anticipate, ***environmental regulations*** or ***conventions*** that apply to Canada. The following categories of expenditures are included: ***pollution abatement and control***; restoration of wildlife and habitat; environmental monitoring, assessments and audits; and site reclamation and decommissioning.

Environmental regulation: Any current or anticipated Canadian federal, provincial or municipal law intended to protect or restore the environment. Examples of environmental regulations include the regulations concerning liquid effluents from the pulp and paper, metal mining and petroleum refining industries made under the *Canada Fisheries Act*.

See also: ***environmental convention***; ***environmental protection expenditures***.

FMS: Acronym for "Financial Management System," the classification of federal government expenditures used in the Public Accounts of Canada, the latter being a principal data source for the Environmental Protection Expenditure Accounts.

Financing criterion: Criterion used to classify ***environmental protection expenditures*** under which such expenditures are attributed to the sector by which they are originally financed, regardless of which sector actually makes the final outlay. Thus, expenditures on waste management by governments are classified to the household sector under the financing criterion, as they are originally financed by households through property taxes.

See also: ***abater criterion***.

GDP: Acronym for ***Gross Domestic Product***.

GIS: Acronym for "Geographic Information System."

Global warming potential (GWP): An index expressing the potential of a given greenhouse gas to contribute to global warming over a specified period (20, 100 or 500 years). The index is measured relative to the warming power of carbon dioxide, which is arbitrarily assigned a value of 1 (Houghton *et al.*, 1996).

See also: ***greenhouse effect***.

Government capital expenditures: Expenditures by governments on new durable assets such as buildings, waterworks, sewage systems, roads, harbours, airports, as well as machinery and equipment.

Synonym: Government investment in fixed capital.

See also: ***capital expenditures***; ***business capital expenditures***.

Government sector: All general departments, agencies and funds (budgetary and non-budgetary) of the federal, provincial and local governments, including locally administered elementary and secondary school systems, plus non-profit hospitals and the Canada and Quebec Pension Plans.

Greenhouse effect: A natural phenomenon whereby certain trace atmospheric gases (referred to as ***greenhouse gases***) absorb a portion of the heat radiating from the planet's surface, trapping and reflecting it back to the earth's surface. Scientists have expressed concern that human-induced changes in the atmospheric greenhouse gas concentrations are significantly enhancing the naturally occurring greenhouse effect (Houghton *et al.*, 1996). This enhancement is predicted to cause warming of the earth's atmosphere and significant disruptions in global climatic systems.

See also: ***global warming potential***.

Greenhouse gases: The group of chemical compounds that are responsible for the so-called ***greenhouse effect***. The most important greenhouse gases produced by economic activity are: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_20) and chlorofluorocarbons (CFC).

See also: ***global warming potential***.

Gross Domestic Product (GDP): An important macro-economic indicator measuring the unduplicated value of the goods and services produced within a nation's boundaries, regardless of the ownership of the factors of production. GDP is estimated in three ways in the ***Canadian System of National Accounts***: as the sum of all income in the economy; as the sum of all expenditure in the economy; and as the sum of value-added by each industry in the economy.

Hotelling model: A model based on the seminal work on natural resource valuation of Harold Hotelling (1931). This model assumes that in a perfectly competitive market the price of the marginal unit of a non-renewable resource–net of extraction, development and exploration costs (including capital costs)–will rise over time at a rate equal to the rate of interest.

See also: ***net price method***.

Household sector: See ***personal sector***.

Indirect-use value: The value associated with the functions (or services) provided by the environment. These include, among others, carbon fixation, the provision of oxygen, ultra-violet radiation absorption and ***waste*** assimilation.

See also: ***direct-use value***; ***market value***; ***non-market value***; ***non-use value***.

Input-Output Accounts: One of the set of accounts comprising the ***Canadian System of National Accounts***. The Input-Output Accounts portray in substantial detail the annual value of commodity flows between industries and consumers. These flows are recorded in three matrices: the "make" matrix portrays the value of each commodity produced by each industry; the "use" matrix portrays the consumption of each commodity by each industry; and the "final demand" matrix portrays the consumption of commodities by households, governments, exports (net of imports), business inventories and capital formation. The Input-Output Accounts yield the benchmark estimate of ***Gross Domestic***

Product against which all other GDP estimates deriving from the CSNA must accord.

Land cover: A description of the physical nature of the land's surface (urban built-up areas or mature forest for example).

Land potential: A description of the biophysical properties of land (climate, geology, topography and soil characteristics for example).

Synonym: land capability.

Land use: A description of the use of land for commercial, non-commercial and ecological purposes.

MEFA: Acronym for "Material and Energy Flow Accounts."

MSAA: Acronym for "Monetary Subsoil Asset Account," a component of the Natural Resource Stock Accounts.

MTAA: Acronym for "Monetary Timber Asset Account," a component of the Natural Resource Stock Accounts.

Market value: The value (or price) that is attributed to a good or service in trade between two economic agents. Market values can be directly observed in the marketplace or estimated using indirect methods.

See also: ***direct-use value***; ***indirect-use value***; ***net price method***; ***non-market value***; ***non-use value***; ***present value method***.

NAMEA: Acronym for "National Accounting Matrix including Environmental Accounts," the environmental accounting framework of the Netherlands Central Bureau of Statistics.

NDP: Acronym for ***Net Domestic Product***.

NMHC: Acronym for "Non-methane hydrocarbon."

NPRI: Acronym for "National Pollutant Release Inventory," a company-specific database of information on releases of a wide range of substances, many toxic, from business facilities in Canada. (Environment Canada is the responsible agency.)

NRSA: Acronym for Natural Resource Stock Accounts.

National wealth: The sum of the values of the non-financial assets held by all domestic sectors of a nation. A related measure, national net worth, is defined as national wealth less net financial claims by non-residents on the domestic sectors of the economy. (Financial assets and liabilities of the domestic sectors do not factor into net national worth, as the financial claims of one domestic sector against another cancel out in the summation of assets and liabilities for the economy as a whole.)

See also: ***Canadian National Balance Sheet Accounts***; ***natural resource wealth***; ***produced capital***.

Natural capital: The natural environment as the source of material resources and environmental services that are necessary for economic activity and human well-being.

See also: ***produced capital***; ***natural resource assets***; ***national wealth***.

Natural resource assets: "Naturally occurring assets over which ownership rights have been established and are effectively enforced...qualify as economic assets and [are to] be recorded in balance sheets. [Such assets] do not necessarily have to be owned by individual units, and may be owned collectively by groups of units or by governments on behalf of entire communities...In order to comply with the general definition of an economic asset, natural assets must not only be owned but be capable of bringing economic benefits to their owners, given the technology, scientific knowledge, economic infrastructure, available resources and set of relative prices prevailing on the dates to which the balance sheet relates or expected in the near future" (Commission of the European Communities *et al.*, 1993; p. 219).

See also: ***tangible non-produced assets***.

Natural resource conservation and development expenditures: Used to describe government expenditures associated with the development of natural resources and with the conservation of these resources. Categories include agriculture, forests, fish and game, mines, oil and gas and "other" (energy efficiency improvement for example).

Natural resource wealth: The value of a nation's holdings of ***natural resource assets***.

nec: Acronym for "not elsewhere classified."

Net Domestic Product: A macro-economic indicator equal to ***Gross Domestic Product*** less the depreciation of fixed capital, or capital consumption allowance.

Net price method: A method used for valuing ***natural resource assets***, based on the so-called ***Hotelling model***, in which the value of a subsoil asset stock is calculated as the ***resource rent*** per unit of asset times the size of the asset stock.

See also: ***present value method***.

Non-market value: The value of a good or service that is based on something other than trade between economic agents. Non-market values include, for example, the value of the environment as a source of ***waste*** assimilation services. Although no transaction occurs in association with the use of these services by economic agents, there is, in theory, a measurable value associated with them.

See also: ***direct-use value***; ***indirect-use value***; ***market value***; ***non-use value***.

Non-use value: The value placed on (or the benefits obtained from knowing about) the existence of natural resources. Bequest value is the value associated with assuring that natural resources are passed on to future generations. Option value is the value associated with assuring the future availability of resources for one's own possible future use (the value placed on maintaining natural resources as future sources of genetic material for example).

Synonym: existence value.

See also: ***direct-use value***; ***market value***; ***non-market value***; ***non-use value***.

OECD: Acronym for "Organisation for Economic Cooperation and Development."

Operating expenditures: Outlays by business or government for labour, fuel, electricity, materials, supplies and other non-durable goods, plus purchased services. The term operating expenditures is used mainly in reference to the ***business sector***; current expenditures is used in reference to the ***government*** and ***personal sectors***.

Synonym: current expenditures.

See also: ***capital expenditures***; ***business capital expenditures***; ***government capital expenditures***.

QRESD: Acronym for "Quarterly Report on Energy Supply-Demand," a principal data source for the Material and Energy Flow Accounts.

PAC: Acronym for pollution abatement and control.

PACS: Acronym for ***Pollution Abatement and Control Survey***.

PSAA: Acronym for "Physical Subsoil Asset Account," a component of the Natural Resource Stock Accounts.

PTAA: Acronym for "Physical Timber Asset Account," a component of the Natural Resource Stock Accounts.

Personal sector: All persons, households and non-profit organisations (such as charitable institutions, labour unions, professional organisations, fraternal societies and universities). Also included are private pension funds and the investment income of life insurance companies.

Synonym: household sector.

Pollution Abatement and Control Survey (PACS): An annual survey run by Statistics Canada through which information on ***pollution abatement and control expenditures*** is collected from businesses. This survey is a principal data source for the Environmental Protection Expenditure Accounts.

See also: ***pollution abatement and control expenditures***

Pollution abatement and control (PAC) expenditures: Outlays for the primary purpose of preventing, abating or controlling the ***waste*** resulting from economic activity.

Present value method: A method used for valuing ***natural resource assets*** based on the application of a ***discount rate*** to an expected stream of future ***resource rent*** returns.

See also: ***net price method***.

Produced capital: Assets such as buildings, machinery, equipment and roads that have been produced by ***economic activity***.

Synonym: produced assets.

See also: ***natural capital***; ***natural resource assets***; ***national wealth***.

Rate of depreciation: An accounting approximation of the value of ***produced capital*** goods "used up" during a given period's production.

Synonym: capital consumption allowance.

Recycling: The diversion of waste materials back into the economy for reuse. The sale of waste material from one process for use in another process may or may not be considered recycling, depending on the circumstances. When undertaken for profit on the part of the waste producer, this type of transaction represents not the recycling of wastes but the exchange of valued goods between economic agents. However, if the sale price of the ***waste*** is intended only to cover the producer's costs in the transaction, the material is considered to be a recycled waste, as it has no positive value to the producer.

Rent: see ***resource rent***.

Reserves: Term used to refer to deposits of subsoil assets that can be assumed with a high degree of certainty to be profitable under current technological and economic conditions. The exact criteria used to define a reserve differs from one subsoil asset to another. Section 3.3 in this volume provides more details.

See also: ***economically recoverable reserves***.

Resource rent: The difference between total revenue generated from extraction of a ***natural resource asset*** and all costs incurred during the extraction process, including the ***cost of produced capital***, but excluding taxes, royalties and other costs that are not directly due to the extraction process. Resource rent serves as the basis for estimating the market value of ***natural resource asset*** stocks in the Natural Resource Stock Accounts.

Return to produced capital: The portion of the revenue earned from an activity that is due the owner of the ***produced capital*** employed in the activity. Return to produced capital is interpreted in the ***Canadian System of Environmental and Resource Accounts*** as the cost of financing the acquisition of the produced capital stock used in resource extraction activities. Financing costs are estimated using a nominal long-term industrial bond rate.

See also: ***cost of produced capital***; ***rate of depreciation***.

SAA: Acronym for “Subsoil Asset Accounts,” a component of the Natural Resource Stock Accounts.

SEEA: Acronym for ***System for Integrated Environmental and Economic Accounting***.

SERIEE: Acronym for *Système européen de rassemblement de l’information économique sur l’environnement*,[1] the environmental expenditure classification of the statistical office of the European Community (Eurostat).

SIC: Acronym for “Standard Industrial Classification,” the classification of industries used by Statistics Canada in its business survey programs (Statistics Canada, 1980).

SNA93: Acronym for ***System of National Accounts 1993***.

Strong sustainability: A form of ***sustainable development*** requiring that both ***natural capital*** and ***produced capital*** be maintained constant over time independently of one another. The assumption implicit in this interpretation is that the two forms of capital are mainly complementary; that is, one is generally necessary for the other to be of any value.

See also: ***national wealth***; ***natural capital***; ***produced capital***; ***sustainable development***; ***weak sustainability***.

1. *European System for the Collection of Economic Information on the Environment.*

Stumpage value: The value of timber “on the stump,” before industrial intervention.

Sustainable development: In its most widely accepted formulation, sustainable development is defined as:

> development that meets the needs of the present without compromising the ability of future generations to meet their own needs (World Commission on Environment and Development, 1987; p. 8).

In the ***CSERA***, *economically* sustainable development is interpreted as:

> development that generates non-declining *per capita* national income by replacing or conserving the sources of that income; that is, the stocks of produced and natural capital (Bartelmus, 1990).

See also: ***weak sustainability***; ***strong sustainability***.

System for Integrated Environmental and Economic Accounting (SEEA): The draft United Nations system for integrating environmental information into the national accounting framework (United Nations, 1993).

System of National Accounts 1993 (SNA93): The internationally accepted guidelines outlining the concepts and methods of the national accounts (Commission of the European Communities *et al*., 1993). Most nations having market-based economies follow the broad outlines of these guidelines when producing their own national accounts.

TAA: Acronym for “Timber Asset Accounts,” a component of the Natural Resource Stock Accounts.

THC: Acronym for “total hydrocarbon.”

Tangible non-produced assets: The ***SNA93*** term for ***natural resource assets***.

Transfers: Payments of funds from one sector to another without *quid pro quo* (government payments to individuals for social assistance for example.) Transfers made for the purpose of financing investment, other forms of accumulation or long-term expenditure by the recipient, or that are made out of the wealth or savings of the donor, are called capital transfers. Those that add to the current income of the recipient are called current transfers.

Waste: Any material/energy that is of no monetary value or material use to the producer and that is disposed of, either directly to the environment or through another economic agent, without remuneration to the producer. This definition encompasses *all* types of wastes, regardless of physical form (gas, liquid, solid or some form of energy) or point of entry into the environment. Material or energy need only be without value or use to its producer for it to be considered waste, notwithstanding any value or use that another economic agent may ascribe to it.

Weak sustainability: A form of ***sustainable development*** that seeks to maintain from year-to-year the *per capita* income generated from the ***produced*** and ***natural capital*** available to a nation. No regard is given to the composition of the nation's total capital stock, on the assumption that produced and natural capital are substitutes for one another. Weak sustainability allows for the depletion or degradation of natural capital, so long as such depletion is offset by increases in the stock of produced capital.

See also: ***national wealth***; ***strong sustainability***; ***sustainable development***.

Wealth: The capacity of an individual, business or country to generate income for itself. Wealth is defined in the ***Canadian System of Environmental and Resource Accounts*** to consist of the combined value of Canada's ***natural resource assets*** and (non-financial) produced assets.

See also: ***natural resource wealth***; ***Canadian National Balance Sheet Accounts***; ***national wealth***.

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