

**MEASURING THE ECO-EFFICIENCY
OF THE FINNISH ECONOMY**

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FOREWORD

This study reviews the economy as a system which provides members of society with both welfare and environmental drawbacks at the same time. It concentrates especially on reviewing the foundations of the new environmental policy strategy of eco-efficiency and analysing the eco-efficiency of the Finnish economy. The objective is to evaluate the serviceability of this approach and to establish a foundation for further studies of eco-efficiency.

Eco-efficiency seeks in practice to combine the economic and material efficiency of production systems and ecological sustainability determined by the carrying capacity of the biosphere and at the same time ensure a sustainable level, at least the one that currently exists, of human needs satisfaction (welfare). The carrying capacity of the global environment sets clear material boundaries on any increase in welfare. These limits are already, according to various studies, being exceeded by the global economy in respect of both environmental pollution and exhaustion of natural resources. A prime objective of eco-efficiency is avoiding the environmental hazards, brought about by production and which eventually lead to decrease in welfare, before they arise.

This report contains the empirical part of my licentiate dissertation and it was first published in Finnish by Statistics Finland in May 1999. The study was directed by Professor Yrjö Haila Ph.D. of the University of Tampere Department of Regional Studies and Environmental Policy. I would like to express my special thanks to him for his encouraging and positive attitude to my research. For expert comments and tips I would also like to thank Emeritus Professor Aarni Nyberg, Ph.D. (Econ.) of the Helsinki School of Economics, Senior Inspector Lari Kuusisto Lic. (Adm.) of the Finnish National Board of Taxes and Professor Jyrki Luukkanen Ph.D. (Tech.) of the University of Tampere. I wish that this study will assist in the implementation of a policy of sustainable development in Finland and will help to promote Finnish and international research and a further expansion of our knowledge in this area.

The English translation of the report has been carried out by European Commission's statistical authority, Eurostat (Directorate B). The theoretical part of the the original study has largely been excluded from this English translation. I would particularly like to thank Mr. Anton Steurer from Eurostat for his assistance and cooperation.

Helsinki, October 1999

Jukka Hoffrén

CONTENTS

Foreword	3
Abstract	5
1 Introduction	7
Description of the subject matter	7
Objectives and content of the study.....	11
2 Eco-efficiency as an environmental policy strategy	14
Problems associated with the concept of economic efficiency	14
Eco-efficiency as a path to sustainable development	17
Measurement of eco-efficiency in practice.....	24
3 Trends in the Finnish environment and economy	28
The natural resource base of the economy	28
The progress of natural resource consumption.....	32
The progress of use of materials, GDP and environmental discharges...	35
Pricing of external effects.....	40
4 Review of the eco-efficiency of the Finnish economy	44
5 International comparison	51
6 Conclusions	59
7 Bibliography	64
Appendix 1. Overall consumption of primary materials	67
Appendix 2. Progress of Finnish economy indicators	68
Appendix 3. Finland's environmental protection costs	70
Appendix 4. Progress of the main environmental impacts in Finland ..	71
Appendix 5. Progress of eco-efficiency in Finland	73
Appendix 6. Eco-efficiencies of economies	74
Principal concepts	75

ABSTRACT

Jukka Hoffrén: Measuring the Eco-efficiency of the Finnish Economy. Statistics Finland, Research Reports 229. Helsinki 1999.

This study examines the possibility of making comprehensive, holistic analyses of the entire environment and economy together. Its particular emphasis is on the economy as source of economic welfare and of environmental impacts, as well as on ways of describing their progress. The study examines and assesses the serviceability of eco-efficiency in detail. The empirical part of the study assesses the progress of Finland's eco-efficiency from 1980 to 1998, bringing together the available research and statistical data on various aspects of eco-efficiency.

The methodology of the study rests largely on the principles of ecologically sustainable development and on theories of economics, especially those of ecological economics such as material flow analysis. Eco-efficiency is examined in the context of the idea of a throughput economy developed in the field of ecological economics. With its quantitative evaluation of progress, eco-efficiency opens up many new opportunities for environmental policy. As welfare grows or remains unchanged, the amount of material bound to commodities will fall, thus producing economic savings and a reduced burden on the environment. The objective is to make production systems economically and materially efficient, while guaranteeing to people a sustainable level of welfare of at least the present standard. The economy will be making progress in eco-efficiency when it improves the quality of life using smaller amounts of natural resources and energy. Besides economic efficiency, production has to be ecologically efficient and sustainable, socially ethical and just. Of these, only economic and ecological factors can be measured in practice.

The study views the environmental problems caused by the economy from the perspective of welfare. For ecological economics, sustainable development means that the level of welfare remains

at least unchanged so that future generations can enjoy at least the present level of welfare. One peculiar problem is how to measure improved quality of life, or welfare. The choice of indicator of welfare will easily change the view of how the eco-efficiency of the economy is progressing. The conventional Gross Domestic Product, which the study had to use to evaluate the development of welfare, is not really an indicator of welfare. In future, other, alternative welfare indicators should be used besides the Gross Domestic Product to describe the progress of welfare. In the measurement of eco-efficiency the so-called primary consumption of natural resources, or Direct Material Input (DMI), is utilised as a measure of society's total materials consumption.

The study indicates that Finland's eco-efficiency appears to have improved over the last 18 years. The use of materials and adverse environmental impacts have shrunk both in absolute terms and in relation to welfare. This trend has been similar in other industrialised countries such as the United States, Germany, Japan and the Netherlands. This examination of eco-efficiency gives reason to believe that, measured by the Gross Domestic Product, the Finnish level of welfare has no longer been bound to increases in material consumption in the 1990s. Achievement of the Factor 10 and Factor 4 objectives would, however, require an average fall of 5.3 per cent per year in material consumption, while the actual decrease has been, on average, some 3.1 per cent during the 1990s. The present rate of progress does not appear to enable us to attain the Factor objectives. Instead new, more effective environmental policy measures are needed to achieve them.

Keywords: *Sustainable development, environmental economics, eco-efficiency, welfare, material flow accounting*

1 INTRODUCTION

Description of the subject matter

The period of rapid economic growth following the end of the Second World War has greatly raised the economic living standards of most of the world's population in many regions. At the same time, however, intensive economic growth has caused growing problems of pollution and waste which have partly undermined the prospects for human flourishing. Since the beginning of 1960s the environmental problems have become the matter of a keen public debate in the industrialised countries. At the end of the 1960s and in the early 1970s societies became aware of the scarcity of the environment and of natural resources as well as of the limits of the present kind of economic growth. At that time very rapid growth of industrial production and population coupled with a rise in the level of welfare seemed to be an impossible combination. The problem of the scarcity of the natural environment became a matter of specific public interest following the publication of the *Limits to Growth* (Meadows et. al. 1974), a report to the Club of Rome in 1972. The report proposed a halt to the economic growth in order to avert the catastrophe threatening mankind. A practical foretaste for economies and for the general public of the scarcity of natural resources arose with the first oil crisis in 1973-75.

Economic theory has proved incapable of providing a response to the questions posed by politicians and the general public concerning the links between economic activity, the scarcity of natural resources, continuous growth of population, environmental problems and welfare. The mainstream economic school of thought, neoclassical economics, remains chiefly interested in individual and local environmental problems and solutions to them, rather than global environmental challenges. In the view of the prevailing scientific theory, major problems can be solved by summing the solutions to partial problems to a comprehensive package. This is also largely the approach of mainstream economics to

the environmental problems facing the world. The principal tools of neoclassical environmental economics to correct the so called external impacts of the production include paying compensation for pollution to those who suffer from it, imposing discharge levies on those branches of industry which cause pollution and shadow pricing and taxation of the free services provided by the environment. In this way an attempt is made to fix the financial value of the problems caused by pollution, depletion of natural resources and growth in waste volumes so that compensation can be paid for local adverse impacts in an optimum manner from society's point of view. None of these approaches is capable of eliminating the problem as such. Instead they can only compensate for the worst anomalies. In spite of a pressing need there is, as yet, no true "environmental macroeconomic theory" which would explain the activity and interactive relationships of the entirety made up of the natural environment and the economy.

It has also been noticed that a production system can be economically efficient in industrialised societies even though in practice it squanders raw materials and energy. The reason for this distortion is largely to be found in the incorrect pricing of natural resources, i.e. of industrial raw materials whereby, for example, no allowance is made in monetary terms for the potential ability of production investments to cause problems of pollution and waste. The inability of economics to allow for environmental issues led to an environmental movement and to scepticism in the mind of the general public concerning the most important instrument of social planning, the System of National Accounts (SNA) and especially its principal indicator, *Gross Domestic Product* (GDP). GDP was viewed as incapable of incorporating the external impacts of economic growth. One of the prime demands of the environmental movement was that such external impacts should be allowed for by developing a "green" GDP whereby environmental problems could be forestalled.

Following greatly increased concern about problems of the environment and natural resources, in the 1970s the United Nations arranged a series of major international conferences, the first of which was the UN Conference on the Human Environment held in Stockholm in 1972. This event was the first to put environmental issues on the agenda of international relations. The international United Nations Environmental Programme UNEP was established in the same year with the objective of bringing together the various United Nations agencies to work for environmental

protection and to formulate proposals in environmental affairs. The significance of environmental issues received a clear boost in the early 1980s when the United Nations set up the World Commission on the Environment and Development (WCED) in 1983 to consider solutions to these problems. In its report "Our Common Future" the WCED (1988, 21-35) took the view that it was necessary to continue economic development because this guarantees developments in technology in a more environmentally friendly direction. The WCED was more concerned about the problem that economic growth does not always guarantee as such that the technology which is best from an environmental point of view will be the one which is used. The WCED also proposed a change in the structure of growth so that it would be less dependent on energy and raw materials and the adaptation of population growth and consumption to match the productive capacity of the natural environment. The Commission called these ideas a policy of sustainable development which "*satisfies current needs and conserves for future generations the opportunity to satisfy their own needs*". The WCED also appealed to the global scientific community to develop theoretical models and tools which complied with new policy of sustainable development.

In the 1990s the policy of sustainable development became the guiding principle of environmental policy as defined at the United Nations Rio de Janeiro Conference on the Environment and Development (UNCED) in summer 1992. The principles of a policy of sustainable development, i.e. adaptation of economic and social development to the framework imposed by natural resources so that the conditions for current welfare are conserved for future generations, were agreed between 178 States. The document known as the Rio Declaration approved by the participating countries at the end of the conference contains a recommendation on principles which can be applied to promote sustainable development. At the follow-up conference (UNGASS) to Rio held in New York in summer 1997 the States of the world confirmed the commitments which they had given in Rio. In practice the necessary changes in the condition of the global environment and use of natural resources have not yet been achieved within the framework of the policy of sustainable development. Agreement on the quantitative objectives of sustainable development has proved extremely difficult to achieve as it is not always easy to bring about a broad international consensus. In concrete terms this was clear in December 1997 when compiling the Kyoto Protocol on the

first globally and legally binding reductions in greenhouse gas emissions.

As a new discipline, environmental policy has not become especially strongly differentiated from practical environmental problems and so the links between research and practical implementation of policy are still fairly close. The System of Integrated Environmental and Economic Accounting (SEEA) compiled by researchers under the auspices of the United Nations Statistical Office to allow for exploitation of natural resources and environmental damage when calculating the value of production was explicitly created to be a policy instrument of sustainable development (United Nations 1993). As the System of National Accounting (SNA) was generally viewed as necessary for its original purpose of describing trends in national economies, natural resources and environmental space were attached to it using separate satellite accounts. Thus the information provided by the SNA could be preserved with a view to the needs of economic life. In practice, however, achieving a consensus on the financial valuation of environmental damage and the use of natural resources proved to be politically impossible in the mid-1990s and no Environmental Accounting in monetary terms was realised. Defining the green GDP is now even more clearly regarded by researchers in the field as an unattainable ideal. The SEEA system is currently being revised and seems to be developing in the direction of a system which is quite separate and independent from the SNA. The new SEEA will probably concentrate on a description of the condition of the environment based on the natural sciences with no link to economic activity. At the same time responsibility for developing environmental accounts is increasingly being transferred from social scientists to natural scientists.

Even though environmental problems have been very much the matter of contemporary public debate for the last 30 years, economic theory has not, in spite of several political appeals, been able to provide any fundamentally new method or instrument for tackling such problems. Often the solutions offered have been based on the application of old ideas to new circumstances and on multidisciplinary examinations. The discipline known as social thermodynamics, which has been applied by ecological environmental economics in particular, has offered some promising prospects for constructing new models. This provides the fundamental principles which are necessary in model construction for systems which are otherwise not susceptible to common measurement.

The combination of the fundamental principles of social thermodynamics with economic theory and welfare is a promising but also extremely difficult area of research.

At the end of the 1990s a new angle known as eco-efficiency has become a promising area of research for those seeking to establish a link between the economy and the environment. The objective of eco-efficiency is to reduce the use of raw materials so as to reduce the environmental impacts such as pollution and waste volumes which are caused by exceeding the carrying capacity of the limited global ecosystem in accordance with the principles of social thermodynamics. The goal is to achieve a sustainable level of satisfaction of human needs (of welfare). Some incentive for the idea of eco-efficiency derives from the fact that several studies show that consumption of materials in the industrialised countries in particular exceeds the replenishment and carrying capacity of the environment. The central challenge for environmental policy research in future will be to turn the comprehensive approach, allowing for all of the complex interactions between the environment and the economy, which is provided by the policy of sustainable development into a practical policy having regard to the fact that the phenomenon known as economic globalisation is continually undermining the means which States have at their disposal to influence the standard of environmental protection within their own regions, thereby hampering independent adoption of environmental taxes and partly also of national environmental legislation. Eco-efficiency then provides a social action strategy which seems most promising.

Objectives and content of the study

This study reviews the formation of total social welfare and particularly the current idea of eco-efficiency as a possible new environmental policy action strategy for society. Eco-efficiency synthesises economic and material efficiency of production systems and the ecological sustainability determined by the carrying capacity of the globe as congruent objectives. The purpose is to present a review of economic ideas of welfare and the point of view of environmental economics concerning environmental impacts. This study will seek to provide an answer to the problem of how the natural resource and environmental efficiencies of the Finnish economy have progressed over the last twenty years and to re-

spond from an environmental policy point of view to the principal question of the future: will we achieve the standard of eco-efficiency imposed by the Factor 4 and Factor 10 objectives at the current pace of progress?

This report is the first study of the progress of the eco-efficiency in Finnish economy. In it, eco-efficiency is examined with the help of the conventional GDP measure, new EDP1-indicator, primary consumption of natural resources (Direct Material Input, DMI) and quantity of environmental hazards. This study is largely based on the economics point of view about the environment. The justification for this is that there are many dependencies and interaction relations between the economy and the environment which are most often perceived from the point of view of the economy and of its functions.

The theoretical frame of reference for this study is neoclassical economics extended with the ideas of ecological economics. In respect of its topic, the study is chiefly located in the sphere of environmental economics, which is a little-practised discipline in Finland. The work is also the first presentation to be compiled in Finland of the overall economic scientific foundations of the notion of eco-efficiency and of its practical application. The compilation of the empirical data used in this study must also be regarded as a pioneering effort. Much of the time series data gathered for the study has not previously been available from any source.

This report contains the empirical part of my licentiate dissertation. The theoretical part of the research has been excluded from this English translation. Chapter 2 examines the concept of eco-efficiency as a new action strategy in environmental policy and as a factor combining the economic and material efficiency of production systems with ecological sustainability. Reducing the use of natural resources and adjusting the structure of economic growth towards qualitative growth requires the development and application of a measure of eco-efficiency. One particularly interesting point in this chapter is eco-efficiency as a way of achieving the sustainable patterns of production and consumption which are necessary for sustainable development. The study also presents earlier methods which have been used to measure eco-efficiency.

In chapters 3 and 4 eco-efficiency monitoring is applied to Finland on the basis of available statistical materials. Initially in chapter 3 a review is compiled of the country's natural resource base, industrial structure and intensity of natural resource use.

Progress in primary use of materials, Gross Domestic Product and principal environmental discharges are also examined. The operation of the measure of social eco-efficiency proposed by the OECD is tested in chapter 4 and the results achieved through its use are examined. Chapter 5 contains a comparison between the eco-efficiency of the Finnish economy and eco-efficiencies of the economies of Germany, Japan, the USA and the Netherlands.

Chapter 6 examines the results obtained through eco-efficiency studies and considers the needs for improvement in this approach. The conclusion of the study goes on to present the principal conclusions to be drawn from the work. The study concentrates on reviewing its subject on the basis of the literature, articles and research reports and available statistical data.

2

ECO-EFFICIENCY AS AN ENVIRONMENTAL POLICY STRATEGY

Problems associated with the concept of economic efficiency

From the point of view of economics, an economy is functioning efficiently when it makes use of all of its available production capacity. If some factors of production remain unused or if they are not used in the optimum manner then the economy is functioning inefficiently. From the point of view of the environment, however, a situation in which part of the productive capacity is left unused is generally better than one in which all resources are in full use and the largest volume of external impacts, pollution and waste also arise. It is already clear from this angle that the economic concept of efficiency alone is an insufficient criterion for an economic policy relevant to sustainable development. Furthermore, there can in principle, be an unlimited number of market solutions which meet the criterion for economic efficiency as the yield from this efficiency can be distributed in society in an unlimited number of alternative ways. Improved economic efficiency is no guarantee of equality, and in practice it may even damage the welfare of some individuals or fail to improve the welfare of the underprivileged members of society. (Randall 1989, 132)

The 1972 *Limits to Growth* report to the Club of Rome (Meadows 1974), the concluding report of the Brundtland Commission in 1987 (WCED 1988) and the 1993 Rio Conference on the Environment and Development (Saurimo 1993) have all considered that besides uncontrolled population growth the underlying reason for the threat of an ecological catastrophe lies in the overuse of natural resources and energy. The science of economics, however, has been more or less incapable of accommodating changes in such factors in its own models. Neoclassical economic

theory and economists have fallen back on old mercantile economic doctrines with respect to natural resources and fossil fuels and have been unwilling to recommend the practical application of new approaches developed in the 20th century, such as the methods of tackling the underpricing of natural resources proposed by Pigou and Coase. The issue also largely concerns the distortion of trade policy between the industrialised countries and the developing countries which produce raw materials. The latter have generally been forced to sell their natural resources at reduced prices because the industrialised countries have sought to keep prices down. In practice the efforts of societies to ensure the availability of cheap raw materials for mass production industry effectively prevent the operation of free market mechanisms and the achievement of efficiency with respect to supplies of these resources.

When the operation of the pricing mechanism is thus prevented in the name of economic growth and development, it has been necessary to develop other means to evaluate the natural resource efficiency of the economy in the industrialised countries. These means are not based on the free market pricing mechanism. The most important of them is the endeavour by Material Flow Accounting (MFA) and Material Flow Analysis to supplement the economic concept of efficiency so as to improve the material efficiency of production systems. The general objective is “to produce more from less” (also known as qualitative growth).

Based on current knowledge, the world's Total Material Input (TMI) exceeds the carrying capacity of the globe and so the present use of raw materials must be reduced in order to avoid a sudden collapse of the ecosystem when the carrying capacity of the environment gives way. The concept of the throughput economy is characteristically one based on the flows of different materials from the natural environment to and through the economy arriving finally back to the natural environment. According to Daly (1991b), the ultimate benefit derived from economic activity is always some given service. The ultimate cost of economic activity, on the other hand, is a throughput of natural resources (a physical flow). This throughput does not directly create the service, but must first be changed into man-made capital stock. All services, however, are originally derived from natural capital stocks and so in fact it is precisely these which satisfy our needs. The man-made capital stocks are merely interim stores comprising organised structures which have been frozen for a while. On one

hand, they provide services, while on the other hand they require new throughputs for their maintenance. Daly (1991b, 36) seeks to express this in the following equation (1):

$$\frac{\text{Service}}{\text{Throughput}} = \frac{\text{Service}}{\text{Stock}} \times \frac{\text{Stock}}{\text{Throughput}} \quad (1)$$

(1) (2) (3)

Ratio (1) of the formula (1) indicates the relationship between throughput and final service efficiency, i.e. the ratio of ultimate benefit to ultimate cost. Ratio (2) is the service efficiency of the stock, ratio (3) the stock-maintenance efficiency of the throughput. The concept of *economic development* consists in increasing ratios (2) and (3), thus getting more service per unit of throughput. *Economic growth*, on the other hand, consists of increasing service by increasing the size stocks, but with no increase (and possibly a decrease) in the efficiency ratios (2) and (3). By holding stocks constant, would force an end to pure growth but would not curtail and in fact would stimulate *economic development* (Daly 1991b, 37).

The increase of ratio (3) (maintenance efficiency) is limited by the second law of thermodynamics as sustainability cannot be limitless. Ratio (2): the efficiency of services obtainable from stocks, on the other hand, has no limits in principle, nor can it be essential from the point of view of a stable state. Only the limits of maintenance efficiency are important. The nature, scope, quality and structure of the capital stock determine the amount of services and the degree of satisfaction of needs can be realised from the stock (Daly 1991b, 37-38).

Efficiency may be defined as the relationship between benefits and costs. When a service is defined as a benefit, efficiency in a throughput economy is simply the relationship between the services which are produced by the economy and the services of the ecosystem which are lost due to such production (Daly 1991b, 78). Expressed as a formula this is (2):

$$\text{Efficiency} = \frac{\text{Benefit}}{\text{Cost}} = \frac{\text{Artifact services gained}}{\text{Ecosystem services sacrificed}} \quad (2)$$

Now on the basis of equation (2) efficiency may be expressed as the following equation (3):

$$\frac{\text{Artifact services gained}}{\text{Ecosystems services sacrificed}} = \frac{\text{Artifact services gained}}{\text{Artifact stock}} \times \frac{\text{Artifact stock}}{\text{Throughput}} \times \frac{\text{Throughput}}{\text{Ecosystem stock sacrificed}} \times \frac{\text{Ecosystem stock sacrificed}}{\text{Ecosystem service sacrificed}} \quad (3)$$

All four ratios (1) - (4) in equation (3) each describe some partial factor. **Artifact service efficiency** (1) describes the efficiency of a given amount of stock in satisfying wants (yielding services) in relation to the services produced. This efficiency depends on its allocation among different artifact embodiments and uses (commodity mix) and on the distribution of the stock among alternative people.

Artifact maintenance efficiency (2) is the turnover or renewal period of the artifact stock. The more durable, repairable and recyclable the stock, the longer things last; then the less maintenance and replacement they require and the greater is maintenance efficiency. **Ecosystem maintenance efficiency** (3) reflects the degree to which an ecosystem can maintain a supply of “throughput yield” on a sustainable basis, that is, without a depletion of the natural stocks

Ecosystem service efficiency (4) depends on the allocation and distribution of ecosystem stock losses. While the price system is of great importance in handling the allocation and distribution of services derived from artifact stocks, it is very limited in its ability to deal with the allocation and distribution of sacrificed ecosystem services. These costs are allocated and distributed mainly through a web of ecological interdependence that lies outside the market. (Daly 1991b, 78-79)

Eco-efficiency as a path to sustainable development

The concept of *eco-efficiency* was first presented by Schaltegger and Sturm in 1990 and was later popularised by Schmidheiny and the Business Council for Sustainable Development (BCSD). The theoretical background to eco-efficiency comes from ecological eco-

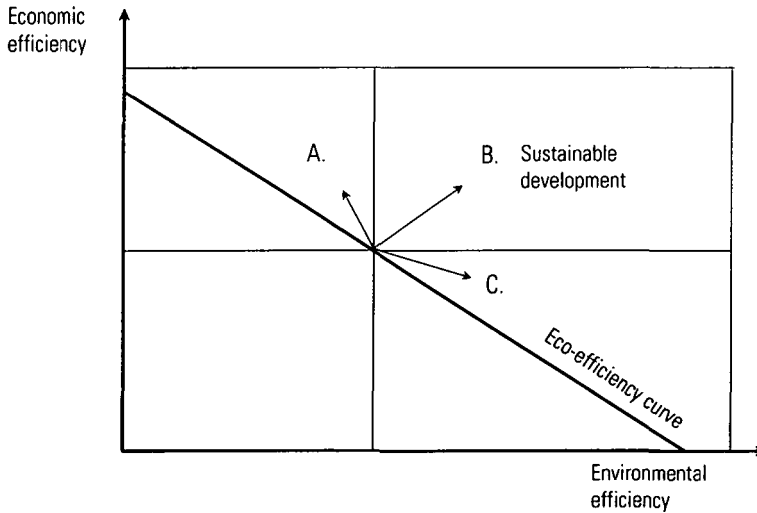
nomics, especially the idea of a throughput economy presented by Boulding, Daly, Ayres and Simonis. Eco-efficiency seeks to combine economic efficiency and the material efficiency of production with the objectives of sustainable development and the notion of social justice under a single heading. At a general level combining these points of view means that the use of materials must be reduced in order to minimise adverse environmental impacts while at the same time ever diminishing amounts of materials should produce a relatively increasing degree of economic welfare which is distributed in an increasingly equitable manner (Helminen 1998, 38).

Schaltegger and Sturm have defined eco-efficiency as the ratio of the desired output per one unit increase in environmental impact. Instead of quality or value, only quantity is considered as output. Ecological efficiency may be divided into two parts: ecological product efficiency (unit of product per additional unit of environmental impact) and ecological function efficiency, meaning the increase in service function corresponding to a single additional unit of environmental impact. A broader perspective is obtained by combining the economic and ecological dimensions under the heading of the ecological efficiency of the economy or eco-efficiency (economic-ecological efficiency, i.e. eco-efficiency), which describes the increase in output corresponding to a single additional unit of environmental impact. The notion of environmental impacts covers all effects on the environment according to their relative degree of environmental impact (Helminen 1998, 39).

Schaltegger et al (1996) have described the relationship between sustainable development and eco-efficiency using figure 1.

In Figure 1 arrows A, B and C describe the paths of development leading to improved eco-efficiency which are available to society. A change in the direction of any arrow above the eco-efficiency curve signifies an improvement in the eco-efficiency of society, even though there is only movement in the direction of sustainable development if both economic and ecological efficiency both improve (arrow B). When such a direction of change arises, economic growth is explicitly qualitative growth obtaining more from less and increasing welfare while reducing environmental impacts. When, on the other hand, the direction of change is only towards economic efficiency (towards area A) there is a loss of environmental efficiency and when change shifts too far towards environmental efficiency (towards area C) there is a loss of economic efficiency. In spite of its utility, Figure 1 is unable to allow for the

Figure 1
Eco-efficiency of sustainable development as an operating strategy



(Schaltegger et. al. 1996, 126; Helminen 1998, 40)

third dimension of sustainable development: social justice, equality and ethics, and this is its greatest weakness (Helminen 1998, 39).

In a document compiled for the United Nations 1992 UNCED Conference held in Rio de Janeiro, the Business Council for Sustainable Development (BCSD) summarised the idea of sustainable development at enterprise level using a concept of economic efficiency which encompassed both economic and ecological efficiency (Helminen 1998, 38). The BCSD viewed eco-efficiency as a means of reducing consumption of natural resources and formation of pollution in the business sector while improving competitiveness. The BCSD presents the following definition of eco-efficiency:

“Eco-efficiency is achieved by providing competitively priced products and services so that human needs are satisfied and the quality of life is assured, while at the same time to an increasing extent the ecological impacts of production over the entire lifespan of the product and its resource intensity are reduced to a level no greater than the estimated carrying capacity of the globe.”

According to the BSCD, an eco-efficient enterprise will implement seven eco-efficiency criteria in its practical operations:

1. Minimise the material intensity of products and services;
2. Minimise the energy intensity of products and services;
3. Minimise toxic dispersion;
4. Enhance material recyclability;
5. Maximise the use of renewable natural resources;
6. Extend product durability;
7. Increase the “service intensity” of products and services.

(Michaelis 1997, 9)

In the mid-1990s several European enterprises set about applying the viewpoint of eco-efficiency in their environmental management and reporting. From the point of view of enterprises the concept of eco-efficiency in practice means taking measures to reduce the use of energy inputs during the life cycle of a product, reducing the use of toxic substances, improving the recyclability of materials, maximising the sustainable use of renewable natural resources, increasing the durability of products and improving their suitability for their purpose. According to the doctrine of eco-efficiency, added value will ultimately accrue both to an enterprise and to society. This accrual will increase the current shareholder value of the enterprise, which is something currently regarded as particularly important. According to a 1993 evaluation compiled by the World Business Council for Sustainable Development (WBCSD, which was named as BSCD until 1995), the greatest bottlenecks in eco-efficiency are current financial incentives, the slow pace of adoption of new kinds of quality thinking, the old ingrained ideas of mass production and resource efficiency, a lack of clarity concerning the objectives of eco-efficiency, the short-term character of commercial thinking and the spread of unsustainable ways of living. Promising ways of promoting eco-efficiency were considered to be correcting price distortion, amending financial incentives, increasing training and finance, reforming designs and improving communications (Helminen 1998, 41).

The Organisation for Economic Cooperation and Development (OECD), an economic forum for the industrialised countries, has shown considerable interest in reducing the use of materials in production. The first OECD discussions on the content of the notions associated with sustainable production and consumption, including eco-efficiency, took place in 1995 at a working conference arranged

in Norway. At a conference of OECD ministers held in February 1996 eco-efficiency was viewed as a promising strategy and it was decided to have feasibility studies conducted on this subject. In a background report on the prospects for eco-efficiency compiled for a conference of OECD environment ministers in March 1998 the basic idea of eco-efficiency is expressed in the following form:

“Eco-efficiency is an action strategy based on the quantitative ratio of input to yield, which seeks to maximise the productivity of energy and materials. The objective is to reduce consumption of resources and environmental discharges for each unit of production while also resulting in cost savings and a competitive edge. Eco-efficiency may also be viewed as a means of guiding the behaviour of enterprises, public authorities and domestic households with a view to making objectives and attitudes more environmentally friendly”.

(Michaelis 1997)

According to the background report compiled for the March 1998 conference of OECD environment ministers, the intensity of energy, materials and land use in relation to GDP is falling at an annual rate of two per cent in the OECD Member States. However, such reductions in the use of natural resources and pollution volumes are insufficient to achieve the Factor 10 efficiency target within the next 30 years. It is estimated that the improvement in material efficiency over the next 30 years will correspond to Factor 2. The current pace of progress will thus not result in global development towards sustainable and equitable models of production and consumption. According to the report, higher degrees of improved efficiency, such as a ten per cent improvement over longer periods and 35 per cent improvements over shorter periods have been achieved under certain circumstances. High degrees of eco-efficiency are typical of high technology sectors in which it has been possible to apply significant scientific inventions to products within very short time periods. (Michaelis 1997, 17)

There has been a great deal of discussion of the economic effects of favouring eco-efficiency. At enterprise level the evolution of technology has led to technical and organisational developments which have helped to achieve the objectives of the business community, of its clients and of environmental policy in general. The effects of this development on society as a whole, on the other hand, have not yet become clear. While improved environmental efficiency may

lead to improvements in other forms of development which improve competitiveness and productivity, many economists in particular believe that limiting the operations of industry can only lead to a fall in financial returns from enterprises. Either point of view may also be justified by appealing to several empirical examples. It has been observed in practice that in rapidly developing sectors with the aid of environmental management systems workers have become involved in creative problem-solving processes which have led to technical advances improving financial returns. On the other hand it has also been noticed that several industrial enterprises operating in long-established sectors of industry, and which have made sizeable investments in standard technologies, have merely endeavoured to meet environmental norms with the aid of additional technology, which has merely resulted in increased expenses. Technological development providing technology capable of manufacturing new, more environmentally friendly and higher quality end products at lower cost has ultimately driven out of the market those enterprises which have invested in old technology (Michaelis 1997, 27-28).

The President's Council on Sustainable Development (PCSD) was appointed in the USA in June 1993 to advise the US President in issues pertaining to the policy of sustainable development and to formulate entirely new methods of harmonising economic, environmental and equality issues. In order to prepare a national plan of sustainable development, the Council initially set up eight task forces to specialise in the following areas: 1. eco-efficiency, 2. energy and transport, 3. natural resources, 4. population and consumption, 5. public relations and training, 6. sustainable agriculture 7. sustainable communities and 8. drafting principles and objectives for sustainable development in these sectors. The report of the eco-efficiency Task Force was completed in 1996. The measures which it recommended to promote eco-efficiency included improving the calculation of economic success by developing the measurement of national output, changing taxation and budgeting policy by promoting international development, combining the economic and environmental points of view in policies for various sectors, particularly agriculture, transport and energy generation, extending the use of economic instruments in environmental legislation and using an industry-specific approach in environmental protection (President's Council on Sustainable Development 1996).

The eco-efficiency proposal prepared by the European Union in April 1997 regards technological and policy development, together

with a change in ways of living and a redefinition of welfare as solutions to the problem of growing demand for products and services and the environmental threat which is brought about by current ways of living. In the opinion of the European Union, The United Nations Committee for Sustainable Development (CSD) should give consideration to eco-efficiency in its work to change patterns of production and consumption so that eco-efficiency may be promoted at national level (European Union 1998). On a proposal by the European Union the practical feasibility of the eco-efficiency objective and the means needed to achieve it were emphasised as an important topic for research in pursuit of changes in patterns of production and consumption in the concluding document of the UNGASS Conference held in New York in June 1997.

Besides subsidy systems that encourage to increase consumption of natural resources, one of the main problems, when reaching to reduce consumption of materials, is the current taxation policy of the industrialised countries which favours the use of natural resources but discourages labour and hiring of employees. According to the environment ministers of the OECD countries, eco-efficiency ought to be promoted in the industrialised countries using, in particular, market signals such as better determination of rights of ownership and internalisation of external costs, i.e. increasing the prices of raw materials. According to the Wuppertal Institute production of primary raw materials may be reduced in practice in several ways, the most important of which are the following:

1. Reducing demand for materials:
 - a) by improving the efficiency in materials use and by ecological design of products,
 - b) by changing patterns of consumption, and
 - c) by shifting demand from products to services,
2. Increasing recycling of products,
3. Increasing the use of solar energy, and
4. Increasing the prices of raw materials and of products which contain large amounts of raw materials.

Shifting the emphasis in taxation to taxing consumption of materials would be the most effective method, even though this is politically very difficult. An very effective method in theory for guiding the use of natural resources in a more eco-efficient direction is to levy taxes on natural resources and on by-products. Most energy and environmental tax by internationally standards is cur-

rently levied on the use of mainly fossil fuels and, according to an OECD report, only in the Canadian State of Manitoba is there a tax on the extraction of minerals by mining and quarrying.

Measurement of eco-efficiency in practice

A large number of indicators have been created to measure achievement of eco-efficiency, all seeking to describe realisation of the objectives imposed. The principal indicators of eco-efficiency monitor changes in the use of natural resources and energy in relation to production. It has not yet been possible to create any generally accepted indicators of eco-efficiency for production, products and services. Besides international comparability, the calculation of eco-efficiency demands relatively easily available, reliable and up-to-date data (Eco-efficiency Task Force 1998, 17). The enterprises which have made a commitment to eco-efficiency have tended to use the dimensions which are susceptible to physical measurement. Formulation of price and welfare indicators is not a straightforward matter, even though financial evaluations form a central element of eco-efficiency. On the other hand some of the partial factors of eco-efficiency listed by the WBCSD can in practice be unsuitable for their purpose (Michaelis 1997, 9).

Along with eco-efficiency, industrial materials exchange, Environmental Space and the formulation and breakthrough of Factor thinking European scientists in the 1990s began to take a broader interest in monitoring overall consumption of the materials used by industry and especially overall consumption of natural resources. In order to guide and coordinate the interest taken in this matter, the ConAccount project (Coordination of Regional and National Material Flow Accounting for Environmental Sustainability), coordinating material flow accounting and analysis, was set up in spring 1996 with the support of the environmental and climate programme of Directorate General XII of the European Commission. The Wuppertal Institute was responsible in practice for coordinating the project, which sought to promote research into material flows and cooperation between researchers working in this field, while establishing links with political decision makers. The ConAccount project established links with 160 material flow projects and 50 other organisations participated as observers. Associated investigations were also conducted into the

use of materials in certain industrialised societies: the USA, Japan, the Netherlands and Germany.

The eco-efficiency of products and services may be measured using the *MIPS-index* (Material Input Per Service) developed in the mid-1990s by the German Friedrich Schmidt-Bleek and the Wuppertal Institute. This index monitors changes in the amount of material consumed for each unit of service produced. The MI-index (Material Input) is the sum total of all material flows brought about by a product or service over its entire lifespan, including both direct and indirect material flows. The material inputs which remain hidden from the consumer are known as the *ecological rucksack* of the product or service. A single kilogram of refined metal used as raw material in industry generally requires tonnes of ore to be extracted from a mine. For example the ecological rucksack of the nine kilogram catalytic converter used in a passenger automobile weighs an average of 2,500 kilograms, a ten gram gold ring has an ecological rucksack of 3,000 kilograms and consumption of a litre of orange juice involves hidden material flows of 100 kilograms. The environmental impacts of consumption are illustrated by an idea known as the *ecological footprint*, in which the material flows required by all products and services are understood in relation to the productive land area required to produce them. The per capita ecological footprint describes the productive land area which a single consumer needs to sustain his level of consumption. (Weizsäcker et. al 1997, 242-244, Eco-efficiency Task Force 1998, 19)

Dow Europe has created a measuring system known as the eco-compass, whereby product innovations may be evaluated in relation to six dimensions of eco-efficiency. In the eco-compass products make up a hexagon. The starting point is a product already on the market for which the value assigned to each dimension is 2 on a scale of 0 to 5. The area formed by the new product's hexagon indicates the difference in eco-efficiency in relation to the existing product. A Danish biotechnology enterprise has developed a measure known as the *Eco-Productivity Index* (EPI), which monitors the annual use of resources by an enterprise. A value of 100 is assigned to the base year of 1990 and the index is calculated in relation to index figures describing the turnover of the enterprise and its use of resources. The Swiss pharmaceutical enterprise Roche has developed the *Eco-Efficiency Rate* (EER) indicator, which is calculated by dividing the value of sales of enterprise production by the environmental protection costs and the total

damage caused to the environment reckoned as a monetary figure. The Canadian communications enterprise Nortel has developed a measure called the *Environmental Performance Index* (EPI) to monitor the progress of operations in relation to the environmental objectives imposed. The index covers a total of 25 variables for environmental discharges and the use of resources, classified under four headings. The index is then calculated as the sum of these parameters allowing for the weighting assigned to each heading. The Canadian National Round Table on Environment and Economy (NRTEE), which promotes the objectives of sustainable development within the country's business community, has proposed the use of three indicators to measure the eco-efficiency of enterprises. These are a material productivity indicator, a toxic discharges indicator and an indicator of the relationship between the costs of solid waste management and sustainability. The NRTEE seeks to achieve a broad consensus on extending the use of these indicators and reducing dependence on a wide variety of currently prevailing indicators (Eco-efficiency Task Force 1998, 19-21; Michaelis 1997, 8-10).

Helminen (1998) has applied the concept of eco-efficiency in a sectoral comparison of industry by comparing the eco-efficiencies of the Finnish and Swedish pulp and paper industries. An eco-efficient production plant is defined in her study as one for which the eco-efficiency ratio (the ratio of added value to environmental impact) is greater than that of a reference plant (Helminen 1998, 82). The study evaluates eco-efficiency using various weighted environmental impact indices alone, nor is any allowance made for use of materials and energy. According to the study, the eco-efficiency of a given production process is determined not only by the available data but also largely according to the method chosen for calculating eco-efficiency.

In a draft report compiled for the OECD Michaelis (1997, 16) has outlined a measure of the eco-efficiency of a national economy. At the level of a national economy the natural resources consumed in production, economic stocks (costs) and environmental stocks are considered to be investments in eco-efficiency and the returns take the form of improvements in the quality of life. Thus one possible, single quantitative measure of eco-efficiency may be expressed on the basis of the following formula (4):

$$\text{Eco-efficiency} = \frac{\text{Improvement in quality of life}}{\text{Costs} + \text{Natural Resources} + \text{Damage}} \quad (4)$$

In formula (4) the term "Improvement in quality of life" actually denotes an increase of one unit of welfare, "Costs" refers to consumption of capital, "Natural Resources" denotes the use of natural resources, i.e. material flows into the economy and "Damage" refers to other adverse impacts caused to the environment by the economy. In practice it is only possible to use such variables in formula (4) that are estimates of some dimensions of the variable. Changes in the variables may be described in the formula using *indicators of various inputs or outputs. Improvements in the quality of life are indicated by such indices as the United Nations Human Development Index (HDI), the ISEW index and various environmentally adjusted indicators of the Gross Domestic Product ("the green GDP"). Environmental damage may be described using various environmental indicators and the use of natural resources may be described using the German DMI and TMR measures of total materials use. Since the variables used in the formula are mutually incommensurable, they must be indexed according to some base year when calculating the actual measure of eco-efficiency. The measure of eco-efficiency thus obtained will then describe the change with respect to some base year. Instead of giving the absolute change, the eco-efficiency index then provides the relative change in eco-efficiency. Thus by using this formula we may make one possible assessment of the progress in eco-efficiency. Although the measure contains many problems and uncertainty factors, it does constitute the only estimate of eco-efficiency which can be calculated. Nothing better has yet been devised for this purpose.*

The summation of various material tonnages into a single measure provides a very rough picture of the state of the environment. From a biological point of view, the use of a small amount of some highly toxic substance in the economy may have greater impact than the use of a much larger amount of relatively harmless stone. Indeed, the hidden assumption behind eco-efficiency concept is that current environmental policy instruments adequately ensure that the ability of various material flows to cause varying kinds of environmental impacts can be neutralised by means of environmental and other social policy measures to a degree enabling the DMI and TMR measures to be compiled and used.

3

TRENDS IN THE FINNISH ENVIRONMENT AND ECONOMY

The natural resource base of the economy

Throughout its history the Finnish economy has largely been dependent on the productive capacity of a living environment and has sought to adapt existing technology to the regenerative capacity and scarcity of the natural environment. The main factors from the point of view of maintaining competitiveness in future years will be caring for environmental capital and improving the information skills which are centred on its use (Kuisma 1997, 226-227). The most important difference between Finland and the other industrialised countries has been that Finland has never had oil or coal reserves of its own upon which the industrialisation of the rest of Western Europe and the USA was based. Also deposits of iron ore and other minerals have been relatively scarce in Finland. The principal factors governing Finnish industrialisation have been its extensive forests, cheap hydroelectric power and relatively well-trained labour force. The industrialisation of Finland after the Second World War occurred somewhat later than that of other Western European countries but was more extensive. Economic growth was based on existing resources such as widespread intensive industrial use of timber resources and hydroelectric power. The industrialisation of Finland was also unanimously supported by all the people. It was viewed that industrialisation will automatically signify an increase in prosperity and turn the country into a modern civilised society. The local environmental drawbacks of increased production were regarded as an inevitable price to be paid for improved prosperity and as something which was of marginal significance in relation to the undertaking as a whole. The economic prosperity which accompanied industrialisation did indeed enable the present affluent society to develop.

Even today Finland's economy and its foreign trade are strongly dependent on the exploitation of natural resources and high levels of energy consumption. The principal sectors are exploitation of forest resources and energy-intensive industrial sectors such as the pulp and paper industry, the basic metal industry and the manufacture of engineering products. Although the structure of Finnish industry has diversified since the 1960s and 1970s, the forest and engineering sectors are still regarded as the backbone of the economy. The forests have been Finland's most important natural resource, although in the 18th and 19th centuries they were exploited in a manner which almost entirely wiped out the woodlands in the near vicinity of villages. Since the 1970s, however, growth of forests has clearly exceeded fellings. At the same time the wood stock has grown from about 1,400 million cubic metres to a current level of more than 1,900 million cubic metres. According to the national inventory of forests, the average annual growth in the wood stock over the period 1989 to 1994 was 75 million cubic metres. Fellings for industrial and other human purposes in 1998 reached a record level of 61 million cubic metres.

The exploitation of wood has posed no threat to stocks in recent years and in this respect Finnish forestry has met the criteria for sustainable development. However, according to the recent OECD land study (1997, 24), for example, the large-scale exploitation of timber resources is the main reason for loss of biodiversity in the Finnish countryside. Remaining reserves of ore are relatively minor in relation to industrial production and those which are currently known are rapidly being exhausted. There has been a clear fall in domestic ore mining output during the 1990s. Since the engineering sector in Finland is very modern, further refining of metals will probably continue in Finland for many years, albeit supplied by raw materials from abroad and by recycling. Most of the steel produced in Finland nowadays is manufactured from iron ore and scrap iron imported from Sweden and Russia (Hoffrén 1998a, 13-14).

One of the most important factor of production in both the forest and engineering industry has been cheap energy. The main source of energy in Finland right up to the end of the 1950s was wood combustion. In the 1960s this energy source began to fall out of use and all new growth in demand for energy was met from oil combustion. After the end of the Second World War new, very abundant oil deposits which could be exploited cheaply were found in the Middle-East and Africa, and this oil drove other en-

ergy sources out of the market. By the end of the 1960s oil was already meeting more than half of Finland's energy needs. It was not until after the first oil crisis in 1973-1975 that the range of available energy sources began to diversify again. Four nuclear reactors were built in Finland during 1970s and 1980s and a gas pipeline from Russia was installed in the 1980s which led to a considerable reduction in oil consumption. While in the 1950s 70 per cent of the national energy requirement was met from domestic sources, by the end of the 1970s this figure had fallen to an established level of 30 per cent, and with some minor fluctuations it remained at this level right up to the 1990s (Laaksonen 1989, 69-72). The most problematic issue from the point of view of the future of the economy is the air pollution caused by energy generation, particularly the increase in carbon dioxide emissions. In an economy based on mass production it is difficult to reduce energy consumption and its associated emissions while keeping the price of energy at a competitively low level. Since natural resources and labour were viewed in the 1990s as scarce factors of production, interest has been shown in increasing the availability of energy and keeping its price low and stable. Even though the Finnish Parliament rejected further construction of nuclear generating capacity in summer 1993, both industry and part of the energy sector have expressed a strong interest in keeping the nuclear option open as a way to reduce carbon dioxide emissions.

Reducing carbon dioxide emissions by means of economic guidance has proved to be very expensive in several studies. According to a forecast made by Pohjola (1997, 49), for example, using an equilibrium model based on neoclassical general equilibrium theory, if Finland reduces its carbon dioxide emissions to the 1990 level by the year 2010 using taxation of carbon dioxide, the country's Gross Domestic Product will fall by 0.8 per cent and there will be a loss of economic welfare of FIM 5.9 billion. The size of the tax would be FIM 275 per tonne, which would sharply increase the relative price of coal and peat and bring about a shift to the use of natural gas. The results provided by this model predict that as a consequence of such a measure the output of the Finnish pulp and paper industry would fall by 20 per cent. On the basis of these calculations industry and the energy sector have condemned as unrealistic the greenhouse gas emission reduction target agreed for Finland in Kyoto and have demanded that this target be mitigated. According to the industrial and energy sectors, it will be technically and economically very difficult for Finland to reduce

its emissions in the manner agreed. These sectors feel that the reduction target originally agreed for greenhouse gases will seriously jeopardise economic growth and the prospects for improved unemployment figures. Ahtiala (1994, 804) has also maintained that it will be expensive for a large but sparsely populated country to be in the vanguard of development unless it intends to turn technological development into an export commodity. Thus stiffer norms than competitor countries for carbon dioxide emissions, for example, are not particularly attractive from the point of view of competitiveness and moderation should be exercised in relation to environmental protection. In practice the views of both Pohjola and Ahtiala have gained widespread social acceptance.

The exploitation of domestic natural resources in Finland is mainly based on a variety of permit procedures. The principal laws governing these are the Environmental Protection Act, the Forest Act, the Extractable Land Resources Act, the Mining Act and the Act on Conservation of Watercourses and the Natural Environment. Industry in Finland has managed to meet its environmental obligations based on this legislation and on other regulations issued by public authorities fairly well. Some leading enterprises have even voluntarily developed environmental protection systems which exceed the legal requirements. Various environmental management and reporting systems are also among the measures which have been introduced and some enterprises have compiled their own environmental policy programmes. These arrangements have also begun to form the basis for calling increasing attention to the issue of reducing the consumption of raw materials by enterprises. At the end of the 1990s, however, there is a danger that primary consumption and the level of environmental discharges may begin to rise again rapidly due to the stimulation of economic growth.

With the exception of fuel used for transport and energy generation, no environmental taxes have been levied in Finland on consumption of natural resources. Most of the current state taxes and charges associated with the environment, including energy taxes, have been introduced on grounds which had nothing to do with the environment. In other words improving the state of the environment was not the original intention of introducing these taxes. In 1999 a total of more than FIM 24 billion was collected in taxes associated with the environment, comprising 12.9 per cent of total revenues. The guidance effect of taxes and charges associated with the environment is most clear in the case of the supplement-

tary tax on alcoholic beverages and soft drinks, the environmentally-based supplementary tax on energy, the oily waste charge, water protection charges, oil protection charges and solid waste tax. These are the taxes which may be described as true environmental taxes. As the total revenues gathered through these taxes and charges amounts to only a few hundred million FIM, their guidance effect is not especially great (see Hoffrén 1998a, 6-8).

The progress of natural resource consumption

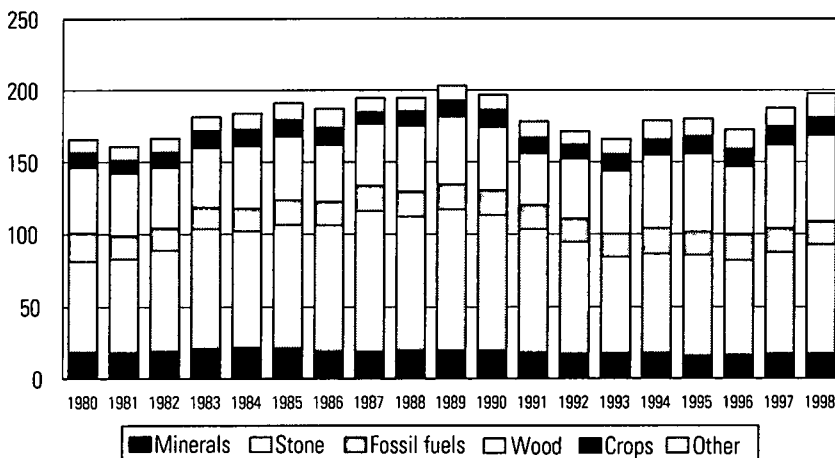
The progress of overall use of natural resources in Finland has been studied by Pekka Mäkelä (1985) of the Centre for Economic Planning, Urho Laine (1994) of the Government Institute for Economic Research and Jukka Hoffrén (1997b and 1998b) of Statistics Finland. The work for Mäkelä's Finland 2000 report examines the use of natural resources in relation to national product and the change in the imputed figure known as *material intensity* over the period 1960-1980, as well as a forecast for their use in the year 2000. Particular emphasis was given in Mäkelä's work to the availability of metals and minerals and the market outlook in these sectors. Laine's work examines overall use of materials in Finland over the period 1960 to 1991, partly on the basis of Mäkelä's data sources, in an effort to thereby formulate an estimate of future use of materials. Laine's report indicates that the increase in the use of materials has been much more rapid than in Mäkelä's forecasts. According to Laine's calculations, nearly 150 million tonnes of primary material were utilised by the economy in 1980 and the corresponding figure in 1990 had already reached 190 million tonnes. According to Mäkelä's forecast the total use should have been only 165 million tonnes at that time. However, Laine predicts that the use of material will fall to 180 million tonnes by the year 2005, i.e. an average annual fall of 0.2 per cent. Laine also notes a fall in the material intensity of use of raw materials at the same time as the relative prices of materials have fallen. According to Laine this is explained by a shift of emphasis in production in the direction of technology, information technology and services.

For the purposes of this study the data previously presented by Hoffrén (1997b, 12 and 1998b, 37) on progress in the use of materials over the period 1980 to 1997 has been re-evaluated. The data on materials use cover the largest materials groups in terms of

tonnage and thereby provide a fairly reliable picture of the direction of change in direct use of materials. The figures differ from those presented by Mäkelä and Laine insofar as instead of measuring consumption of raw materials they primarily describe the consumption of primary materials, natural resources and biomass which human beings utilise to produce the commodities and services required for their welfare (Hoffrén 1998b, 36). Material consumption is considered to comprise the uptake into the production processes of the economy of ores, minerals, limestone, peat, stone material (gravel, sand and rocky materials), wood, fossil fuels, cultivated resources produced in agriculture and market gardening, forest by-products (berries, mushrooms and game) and fisheries output (the catch from professional and recreational fishing). The estimate does not include consumption of air and water, for which no reliable statistics are available. The materials on the progress of overall consumption of natural resources in Finland over the period 1980 to 1998 is presented in graphical form in Figure 2 and in greater detail in statistical appendix 1.

As can be seen from Figure 2, the quantitatively largest material flows are those of stone materials and wood. In 1997, for example, the proportion of stone material (gravel, sand and rocky materials) in direct overall consumption of natural resources was 38.5 per cent, while the corresponding proportion of wood was 30.6 per cent. Domestic ores, minerals and limestone accounted

Figure 2
Consumption of materials in Finland 1980-1998 (million tonnes)

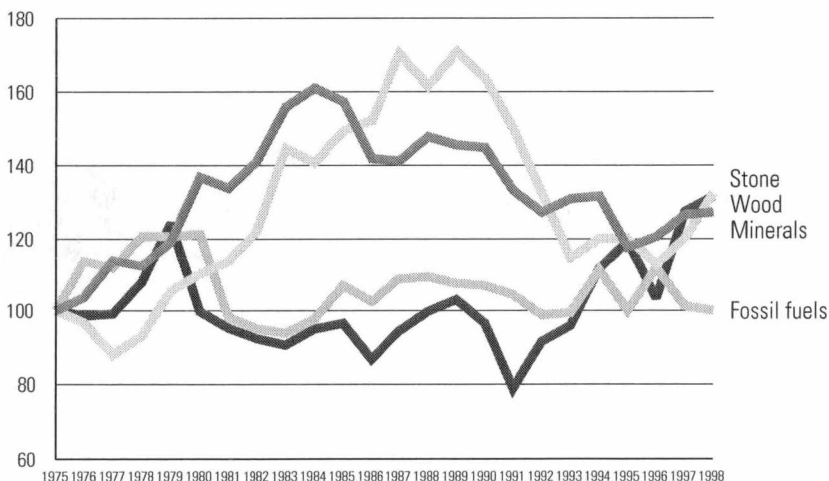


for 8.8 per cent, fossil fuels for 8.2 per cent and cultivated crops 6.1 per cent. The remaining 8.6 per cent comprised peat, fish, market garden produce, game, forest by-products and imported metals. Overall the total amount of primary materials consumed in Finland in 1998 is estimated at 197.7 million tonnes. 115.7 million tonnes of this consisted of non-renewable natural resources and 82 million tonnes were renewable natural resources.

In absolute terms the consumption of materials in Finland increased at a more or less steady rate throughout the 1980s and right up to the time of the economic recession of the early 1990s, at which point the use of materials fell sharply. Materials consumption reached a peak of 203.1 million tonnes in 1989 and a lowest point of 166.2 million tonnes in 1993. Towards the end of the 1990s consumption of materials has once again begun to rise but in quantitative terms overall consumption still remains below the peak level of 1989. The progress in consumption of the materials which are consumed in the greatest quantities is described in greater detail in Figure 3. In this figure the material flow tonnages have been indexed to a base year of 1980 in order to facilitate the review of progress.

As will be noticed from Figure 3, consumption of stone materials fell very sharply at the end of the 1980s. Consumption of domestic extractable land resources has also been falling since the early 1980s. On the other hand there was a corresponding sharp

Figure 3
Consumption of materials consumed in the largest quantities in Finland 1975-1998
(1975=100)



rise in consumption of wood in the early 1990s. According to forecasts, the growth in Finland's wood resources, arising from the largely young age structure of the forests and from efficient forest management, will continue for at least the next 15 to 20 years. Consumption of fossil fuels has remained fairly steady over the period reviewed. The structure of Finland's energy consumption has actually remained the same for the last ten years with fossil fuels accounting for about 46 per cent of energy consumption.

Consumption of gravel and other stone materials reached a peak at the end of the 1980s due to a high level of construction activity. After this fell sharply in the recession years of the early 1990s there was a fall in the volumes of gravel extracted. Extraction of gravel has been greatly dependent on the state of the economy. The amounts of gravel and sand reserves available also vary considerably by region. As gravel reserves have decreased in the vicinity of built-up areas, there has been a rapid rise in the manufacture of crushed rock, particularly in the Helsinki Metropolitan Area and on the West Coast of Finland. There is also a shortage of certain stone materials such as the highest quality gravels needed for the construction industry. The amounts extracted from Finland's own ore mines have also decreased rapidly. In relation to industrial production in Finland, the remaining ore deposits are minor and those which are known are rapidly being exhausted. It is estimated that by the beginning of the 21st century only one of the present ore mines will still be operating.

*The progress of use of materials, GDP and
environmental discharges*

The System of National Accounts (SNA) and particularly the Gross Domestic Product (GDP) indicator are generally used in Finland to describe the operations of the economy. The earliest estimation of national wealth in Finland was the calculation made by Mr. Karl Emil Ignatius for the period 1881-1882 (Hjerppe 1989, 426). This early story of national product accounting ended with the transfer of Ignatius away from the statistical sector and the abolition of the appropriation tax which was based on his system. After this episode there was a break of 40 years in official calculations of the national product (Marjomaa 1986, 37) and it was not until 1922 that the Finnish "national product" was once

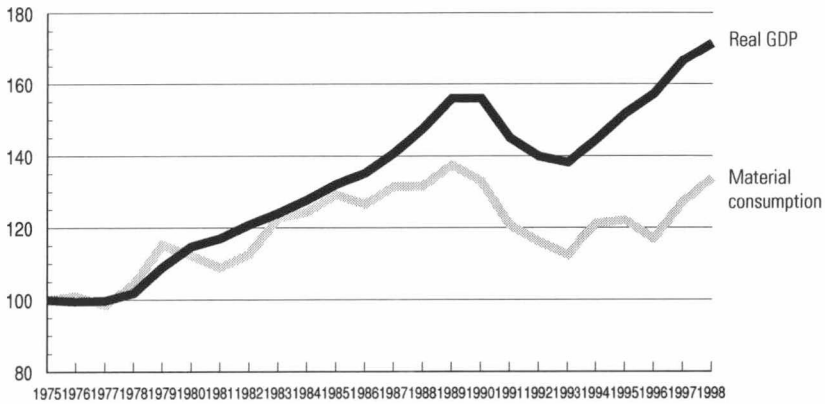
again calculated. Compiling of the official national product based on Keynesian macroeconomic theory and international recommendations began in Finland in 1948. Since 1978 the System of National Accounts has been compiled according to a United Nations SNA-68 recommendation and is currently being revised to comply with the corresponding new SNA-94 and European Union ESA94 recommendations. The evolution of Finland's Gross National Product calculated according to the SNA-68 recommendation over the period 1975 to 1998 is shown in statistical appendix 2 to this investigation. Table 1 shows the evolution of materials consumption, real GDP and population in Finland over the period 1980 to 1998.

On the basis of the information shown in Table 1 preliminary examinations may be made of the progress of materials consumption in the Finnish economy. Since the use of the real GDP indicator provides a more reliable picture of the evolution of economic activity in time series analyses, I have selected selected this very indicator and the environmentally adjusted national product as

Table 1
Materials consumption, real GDP and population in Finland in 1980-1998

	Consumption of materials (million tonnes)	Real GDP (FIM million)	Population
1980	165.8	379,294	4,788,000
1981	160.9	386,361	4,800,000
1982	166.4	398,907	4,826,000
1983	181.3	409,690	4,855,000
1984	183.6	422,048	4,881,000
1985	190.9	436,258	4,911,000
1986	186.9	446,606	4,926,000
1987	194.2	464,917	4,939,000
1988	194.4	487,719	4,954,000
1989	203.1	515,364	4,974,000
1990	196.5	515,430	4,998,000
1991	178.3	479,011	5,029,000
1992	171.6	462,003	5,055,000
1993	166.2	456,571	5,078,000
1994	179.0	477,340	5,099,000
1995	180.3	501,490	5,117,000
1996	172.7	519,322	5,132,000
1997	187.6	550,532	5,147,000
1998	197.7	566,729	5,160,000

Figure 4
Real GDP and direct material consumption in Finland in 1975-1998 (1975=100)

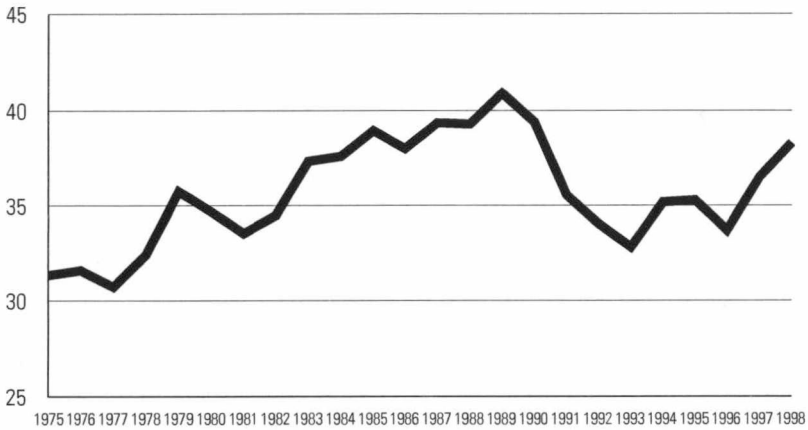


indicators of welfare in this study. Table 1 shows that Finland's consumption of materials was more than 19 per cent higher in 1998 than it was in 1980. Moreover there was an increase of nearly 50 per cent in real GDP over the period from 1980 to 1998. Over the same period population growth in Finland was fairly stable, rising by only 7.8 per cent. The progress of Finland's real GDP (at 1990 prices) and use of materials over the period 1980 to 1998 is examined in Figure 4. The data in Figure 4 are also presented in statistical appendices 1 and 2.

The curves in Figure 4 for both real GDP and material consumption describe the changes in the values of these variables compared to a base year of 1980 for which the values are 100. On the basis of Figure 4, the progress of economic production in Finland at the end of the 1980s and during the 1990s has been intensive, i.e. from smaller amounts of materials it has been possible to produce greater amounts of wealth as measured by the Gross Domestic Product. Consumption of materials may also be assessed in relation to population so that progress can be evaluated using the concept of Environmental Space describing the overall amount of consumption of natural resources according to the principles of sustainable development. The per capita use of materials in Finland over the period from 1980 to 1998 is examined in Figure 5.

Figure 5

Per capita use of materials in Finland in 1975-1998 (Tonnes per capita)

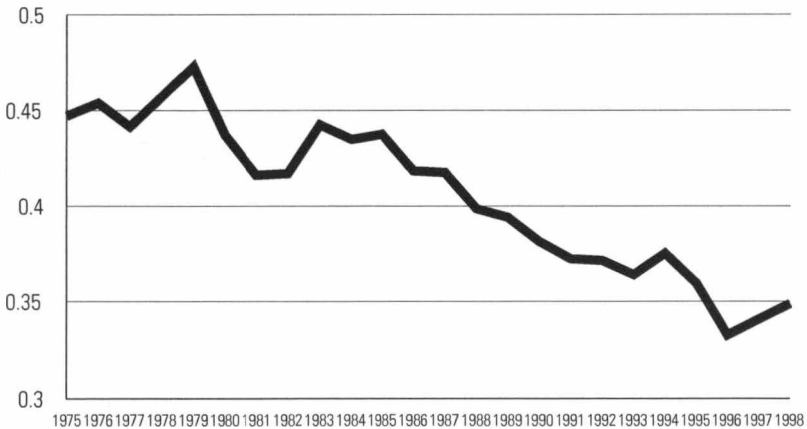


According to Figure 5, the per capita overall annual consumption of natural resources during the period under review has varied between 31 and 40 tonnes. An estimated 38 tonnes of natural resources per head of population were consumed in 1998. Figure 6 shows the use of materials per unit of real GDP over the period from 1980 to 1998.

According to Figure 6, direct overall consumption of natural resources per unit of GDP has fallen from 0.41 kilograms per

Figure 6

Use of materials per FIM GDP in Finland in 1975-1998 (Kilograms per FIM)

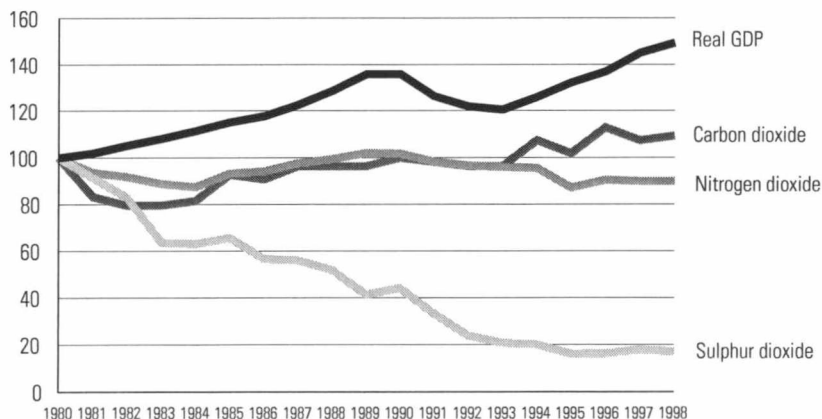


FIM in 1980 to 0.35 kilograms per FIM in 1998. In other words, even though consumption of materials by the economy in Finland has not fallen very much in absolute terms, the amount of material needed to produce a single FIM of output has fallen clearly.

According to the idea of a throughput economy, material flows cause a corresponding magnitude of environmental impacts if the standard of production technology remains the same. The standard of the available data is inadequate for a time series examination of the amounts of natural resources used, the amounts of solid waste produced and the degree of pollution caused because of the lack of annual solid waste statistics. Instead it is possible to compare the progress of real GDP and the principal aerial emissions over the period from 1980 to 1998. Since comprehensive statistics of overall polluting discharges of the Finnish economy have been compiled only in recent years, no examination over a longer period has been possible. Figure 7 shows the evolution of Finland's real GDP and principal aerial emissions over the period from 1980 to 1998.

On the basis of Figure 7 it may be held that Finland's Gross Domestic Product has grown since 1980 more rapidly than its emissions of sulphurous, nitrogenous and carbon dioxide pollutants. Administrative measures have been highly successful in reducing sulphurous emissions and Finland has also succeeded in reducing traditional environmental pollution. Aside from aerial emissions,

Figure 7
Real GDP and atmospheric emissions in Finland in 1980-1998 (1980=100)



reductions have been achieved in lead emissions and acidifying fallout as well as industrial and domestic waste water discharges and other forms of pollution. It should also be remembered that the environmental policy pursued by Finland in the 1970s and 1980s concentrated on water protection. Only later was attention paid to air protection and investments began to be made in this in the early 1980s. Calculated in terms of tonnage, a total of more than 56.4 million tonnes of aerial pollutants were discharged in 1998.

Besides aerial emissions, it is estimated that nearly 88.5 million tonnes of solid waste are produced in Finland each year, of which 35.5 million tonnes arise in ore and mineral mining. 15.5 million tonnes of industrial waste were formed, of which the forest industry accounted for half, the metal and engineering sector for one fifth and the chemical industry for less than one fifth. A total of 58 per cent or 9 million tonnes of industrial waste was recycled. 22 million tonnes of agricultural waste were produced, of which manure accounted for 21.5 million tonnes. The total amount of waste produced annually by domestic households is nearly 900,000 tonnes. The largest single type of domestic waste is biological waste, i.e. plant and animal waste which easily degrades under natural conditions. No precise time series data are so far available on the total amount of waste and on the direction of progress in this sector. The total combined amount of pollutants and waste arising annually in Finland is thus estimated at 150 million tonnes.

Pricing of external effects

According to formula (4) presented in chapter 2, inputs of the eco-efficiency are the natural resources consumed in production, economic resources (costs) and environmental resources while the output is the improvement in the quality of human life. The eco-efficiency indicator then shows how much improvement in quality of life has been achieved in each year in relation to a single unit of input. Indicators of various inputs and outputs can be used as variables in the calculation of eco-efficiency. Improvement in quality of life is described by such indicators as the United Nations Human Development Index (HDI) and by various environmentally adjusted GDP ("green" GDP) figures. Environmental damage may be described using various environmental indicators

and the use of natural resources using the DMI indicator describing total (direct) material use of an economy.

The most reliable measure of the "green GDP" is the Environmentally Adjusted Domestic Product (EDP) which is the leading indicator of the United Nations SEEA system and is intended to facilitate measurement of the true level of welfare of a society and to assist decision making. According to a manual published by the United Nations (United Nations 1993), the EDP can be obtained by adding revenues from foreign production factors and indirect taxes to the GDP at market prices and deducting from this the sum of fixed capital consumed, environmental protection costs and other changes in the value of environmental resources. Calculation of the EDP mainly requires deduction of consumption of fixed capital (man-made capital) and of environmental resources (environmental capital) from the value of the traditional GDP.

Table 2
Finnish environmentally adjusted GDP in 1990-97 (FIM million; current prices)

	1990	1991	1992	1993	1994	1995	1996	1997
<u>SNA-68</u>								
GDP	515,430	490,868	476,778	482,397	510,992	549,863	574,027	622,106
Factor incomes from ROW	-15,040	-19,569	-24,811	-29,763	-23,426	-20,013	-19,308	-16,596
Indirect taxes from ROW	-	-	-	-	-	-1,029	-984	-980
GNP	500,390	471,299	451,967	452,634	486,498	527,821	553,735	604,530
Consumption of fixed capital	-79,512	-82,170	-81,892	-83,819	-85,480	-87,027	-87,632	-90,974
NDP	420,878	389,129	370,075	368,815	402,086	440,794	466,103	513,556
<u>SNA-94 :</u>								
Growth of forests	2,914	3,839	2,502	2,065	1,506	1,523	2,416	2,400
<u>SEEA :</u>								
Environmental expenditure	-5,956	-6,182	-8,206	-8,050	-7,473	-9,319	-9,958	-10,864
EDP 1	417,836	386,786	364,371	362,830	396,119	432,998	458,361	505,092
Other changes in the value of environmental assets*)	-12,588	-12,711	-11,926	-10,882	-11,952	-10,634	-11,909	-11,258
EDP 2	405,248	374,075	352,445	351,948	384,167	422,364	446,652	493,834

ROW = Rest Of the World - = not in use *) = estimate

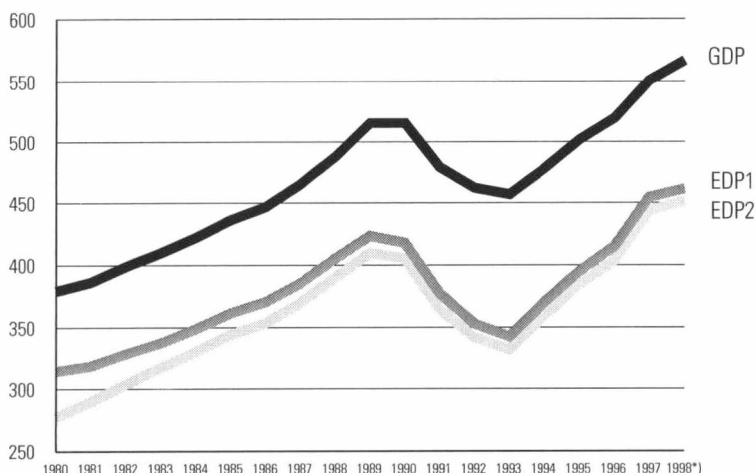
(Source: Hoffrén 1997a)

Consumption of fixed capital is, in practice, already accounted for in calculating the net domestic product and so the only problem remaining is to compile reliable statistics of environmental protection costs and an evaluation of changes in stocks of natural resource and of the environmental impacts of production. A calculation of the EDP time series for Finland according to the SEEA system has been presented earlier by Hoffrén (1997a, 103). This calculation has been updated for the purposes of the current study in Table 2.

The concept *Growth of forests* in Table 2 includes the unharvested growth of wood stock in Finland's economically exploited forests according to the SEEA manual. The growth data for forest stocks are based on information gathered by the Finnish Forest Research Institute and Wood Material Accounts data from Statistics Finland. The unharvested growth of forests is priced on the basis of stumpage price data for each year. *Environmental protection expenses* comprise actual expenditure by the State, by municipalities and municipal federations, by industry and by environmental organisations to improve the condition of the environment and of natural resources. There is a more precise breakdown of environmental protection expenses in statistical appendix 3. The concept *Other changes in the value of environmental resources* covers other values of external impacts caused by the economy. In Table 2 this point contains an evaluation of acidifying fallout caused by Finland's emissions of sulphur and nitrogen, of needle loss in forests and of the financial values of carbon dioxide emissions and the fixation of carbon by forest growth. The financial value applied to carbon fixated in unharvested timber stocks is taken from the figure of FIM 170 per tonne used in project planning by the Finnish National Road Administration. The value for acidifying fallout corresponds to the FIM 22,000 value previously used by the International Institute for Applied Systems Analysis (IIASA) in its research projects into environmental technology (for further details see Hoffrén 1997a).

As can be seen from Table 2, consumption of fixed capital in Finland clearly exceeds estimated consumption of environmental capital by a factor of four or five times depending on the year. This is certainly due to the fact that in the absence of any reliable way of assessing prices no effort at all has been made in this calculation to set prices on anything close to all of the known environmental impacts. The progress of Finland's real GDP, EDP1 and EDP2 in relation to one another over the period between 1980 and 1998 is examined in Figure 8.

Figure 8
Developments of real GDP, EDP1 and EDP2 in Finland in 1980-1998 (FIM billion)



*) = estimate in accordance with the SNA-68 recommendation

As can be seen from Figure 8, the developments of the GDP, EDP1 and EDP2 curves are nearly precisely the same, only the level differs. This is due to correlating changes in economic variables. In particular the dominant role of fixed capital in calculating EDP conceals the values of the environmental variables. The difference between EDP1 and EDP2 does not seem to be particularly large, which is obviously due to the fact that it has not been possible to take full account of environmental impacts, nor to set the “correct” prices for them. The EDP is indeed specifically deficient as a measure of welfare and this should be borne in mind when using it. A better measure of welfare would be an ISEW-type welfare indicator for a sustainable economy. The data necessary to calculate this is not available, however. The calculation presented of Finland’s EDP1 may, however, be regarded as a better measure of welfare than the GDP. Therefore the following figures use an environmentally adjusted national product of type EDP1 as a measure of welfare in evaluating Finland’s eco-efficiency.

4

REVIEW OF THE ECO-EFFICIENCY OF THE FINNISH ECONOMY

In their most simplified form, economic efficiency key figures express output in relation to expenses, i.e. efficiency is yield over cost. The larger this figure is, the more efficient and productive is the function concerned. When output and expenses are the same size, then the efficiency ratio is 1. If the efficiency figure falls below 1, then the function is clearly inefficient. In this licentiate thesis the eco-efficiency of the Finnish economy is evaluated according to the formula (4) proposed by Michaelis (1997). As the System of National Accounts (SNA) is based on the assumption that the expenses and income of the economy are by definition equal in magnitude, it is not possible to calculate efficiency at the level of the national economy in quite the same way as is done in the business world. For national economies the most efficient condition is the one in which the actual GDP corresponds in magnitude to the potential GDP, meaning that all resources are fully employed. From the point of view of the environment, however, such a situation is not always the most desirable, nor the most efficient.

In this research report the overall efficiency of the Finnish economy will be studied as the progress of relationship between the real EDP and consumption of natural resources and the volume of environmental hazards. Because of the incommensurability of variables an indexation scheme is used whereby the starting year 1980 is indexed as 100. Annual changes thus describe how the variables behave in each year in relation to this base year. The measure of the EDP1 employed is based on the United Nations SEEA system and its practical compilation for this study is based on the official Finnish SNA calculations and on the data presented in the *Finland's Natural Resources and the Environment 1999* -review. The progress in the real EDP1 is presented in a statistical appendix 2. In this report the concept consumption of natural resources means really the so-called "primary" consumption which prevents

double counting. In practice consumption of natural resources includes the amount of usable stone extracted from domestic mines, consumption of stone material, clay and peat, imports of metals and minerals, use of fossil fuels and production from cultivated fields, market gardening produce, use of wood, forestry by-products and fishing catches, and production of fish farming. No effort has been made in this study to assess the relative harmfulness associated with the use of various materials. Progress in consumption of natural resources is presented in a statistical appendix 1. Environmental damage includes the principal atmospheric emissions, i.e. sulphurous (SO₂), nitrogenous (NO_x) and carbon dioxide (CO₂) emissions together with water pollution, i.e. by phosphorus and nitrogen compounds. These variables were selected due to the availability of data. Neither has any weighting been assigned to environmental drawbacks according to their degree of harmfulness because of the difficulty of determining any such weighting and considerable scope for disagreement on this topic. Progress in environmental damage is presented in a statistical appendix 4.

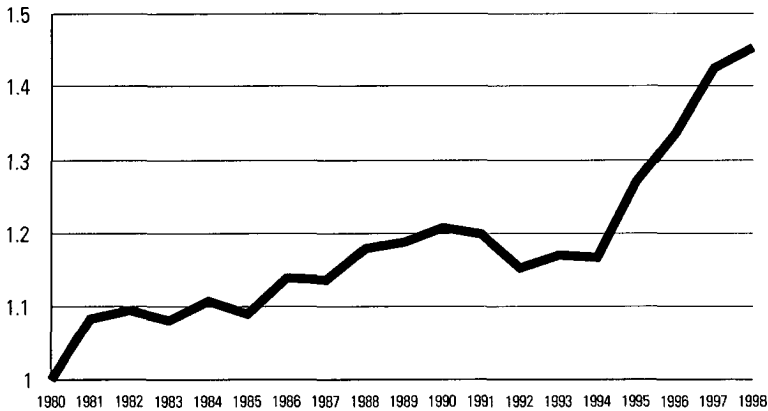
The overall efficiency (Eco-efficiency 1) of the Finnish economy is evaluated using the following formula (5) (see Michaelis 1997, 12):

$$\text{Eco-efficiency 1} = \frac{RE}{((L + V) / 2)} \quad (5)$$

where: *RE* is the real, environmentally adjusted national product according to SEEA (EDP1),
L is the primary consumption of natural resources, and
V is the change in the amount of environmental damage.

As the variables used in formula 1 are expressed in various units of measurement, indices are used for RE, L and V instead of the value units of these variables. A value of 100 has been assigned to all of these variables in the base year of 1980. The indices for other years thus express the change with respect to the 1980 value. The values of the variables are presented in appendices 1, 2, 4 and 5 of this report. The results obtained using formula (5) are shown in Figure 9 and in statistical appendix 5 of this research report.

Figure 9
Overall eco-efficiency of the economy in Finland in 1980-1998 (Eco-efficiency 1)



As will be noticed from Figure 9, the total eco-efficiency of the Finnish economy has clearly improved since 1980 with the exception of the economic recession of the early 1990s. Compared to 1980, by 1998 Eco-efficiency 1 had improved by a total of 45.3 per cent. The most rapid improvement was during the period from 1995 to 1998 at a time of rapid economic growth. Achievement of the Factor 10 and Factor 4 objectives, however, would require an average annual improvement in eco-efficiency of 5.3 per cent. The average annual decrement achieved over the period between 1980 and 1998 was only 2.5 per cent with an average of 3.1 per cent even during the 1990s. Based on the progress achieved, the present rate of improvement will not lead to attainment of the Factor objectives and new, more effective environmental policy measures will be needed to achieve these objectives.

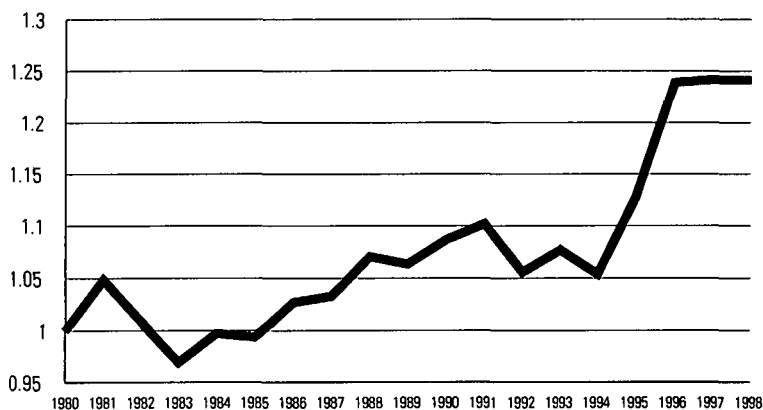
The material efficiency of the economy has been studied using the following Eco-efficiency 2 formula (6) (for further details see Adriaanse et. al. 1997, 14):

$$Eco\text{-}efficiency\ 2 = \frac{RE}{L} , \quad (6)$$

where: *RE* is the real environmentally adjusted national product (EDP1), and

L is the primary consumption of natural resources.

Figure 10
Efficiency of materials use in the economy in Finland in 1980-1998 (Eco-efficiency 2)



The results obtained using formula (6) are presented in Figure 10 and in statistical appendix 5 to this research report.

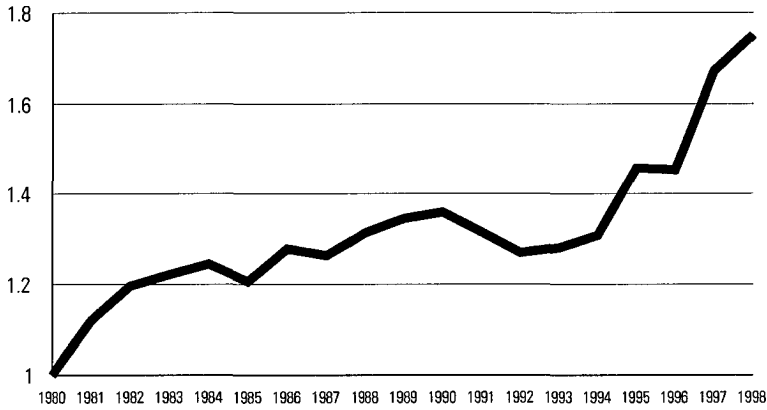
As can be seen from Figure 10, the material efficiency of the Finnish economy fell in the mid 1980s, after which it has improved. The most rapid growth was during the period from 1995 to 1996. Compared to 1980, Eco-efficiency 2 improved by 24.1 per cent by 1998. It is interesting to notice that the eco-efficiency 2 almost achieved its current peak level already in 1996 and has remained relatively the same in 1997 and 1998. Achievement of the Factor 10 and Factor 4 objectives, however, would require an average annual fall in use of materials of 5.3 per cent right up to the year 2040. The average fall which was achieved over the period 1980 to 1998, however, was only 1.3 per cent and even over the period 1990 to 1998 the corresponding rate was just 1.9 per cent. With such an outlook the current pace of progress will not be adequate to achieve the factor objectives.

The relationship of the amount of environmental hazards caused by the economy to the progress of welfare has been evaluated using the following Eco-efficiency 3 formula (7):

$$\text{Eco-efficiency 3} = \frac{RE}{V} , \quad (7)$$

where: *RE* is the real environmentally adjusted national product (EDP1) and
V is the change in the amount of environmental hazards.

Figure 11
Efficiency of correction of hazardous environmental impacts caused by the economy in Finland (Eco-efficiency 3)



The results obtained by using formula (7) are presented in Figure 11 and in statistical appendix 5 to this research report.

The environmental drawbacks caused by the economy have fallen rapidly in relation to the welfare which it has generated, although the recession of the early 1990s slowed this process down somewhat. Eco-efficiency 3 improved by more than 75 per cent between the base year of 1980 and 1998.

The relationship between progress in atmospheric emissions and welfare has been studied using the following Eco-efficiency 4 formula (8):

$$\text{Eco-efficiency 4} = \frac{RE}{IP} \quad , \quad (8)$$

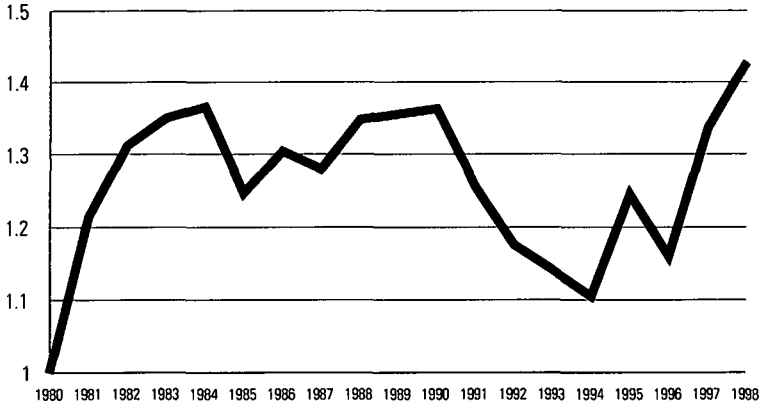
where: *RE* is the real environmentally adjusted national product (EDP1) and

IP is the change in tonnage of sulphur, nitrogen and carbon dioxide emissions.

The results obtained using formula (8) are presented in Figure 12 and in statistical appendix 5 to this research report.

According to Figure 12, the improvement in the Eco-efficiency 4 indicator in the early 1990s seems to have clearly reversed, although efficiency has once again begun to improve since 1995.

Figure 12
Efficiency of cleaning of atmospheric emissions of the economy in Finland
(Eco-efficiency 4)



Compared to the base year of 1980, Eco-efficiency 4 had improved by 42.8 per cent by the year 1998.

The relationship between the progress of water pollution and welfare has been studied using the following Eco-efficiency 5 formula (9):

$$Eco\text{-}efficiency5 = \frac{RE}{VP} , \quad (9)$$

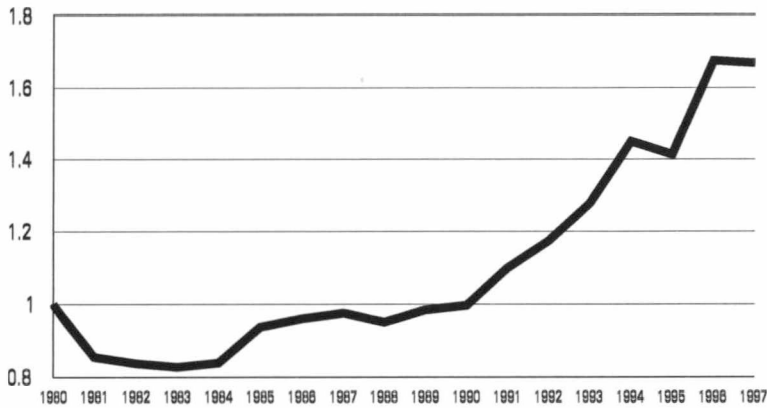
where: *RE* is the real environmentally adjusted national product (EDP1) and

VP is the change in the emissions of nitrogen and phosphorus pollution into the waters.

The results obtained using formula (9) are presented in Figure 13 and in statistical appendix 5 to this research report.

Economy's emissions into the waters clearly grew more rapidly than welfare generated by the economy throughout the 1980s. It was only in the 1990s that water pollution began to fall rapidly with respect to the volume of production. Compared to the base year of 1980, Eco-efficiency 5 improved by as much as 58.5 per cent by the year 1997, thanks to the favourable development which took place in the 1990s.

Figure 13
Efficiency of reduction of water pollution by the economy in Finland
(Eco-efficiency 5)



Examined using these Eco-efficiency 1-5 ratios, the eco-efficiency of the Finnish economy has improved dramatically in the 1980s and 1990s. On the other hand, the progress made by the various partial factors in eco-efficiency has been very widely divergent. The improvement in eco-efficiency in the 1980s was due to a fall in aerial emissions, as there was a clear fall in eco-efficiency with respect to consumption of natural resources and pollution of watercourses. On the other hand the improved eco-efficiency of the economy at the end of the 1980s and in the 1990s was due to a clear improvement in the efficiency of primary consumption of natural resources and a reduction in pollution of watercourses, even though there was a loss of efficiency in respect of aerial emissions, particularly of carbon dioxide and nitrogen oxides.

5 INTERNATIONAL COMPARISON

The eco-efficiency of the Finnish economy has not been compared to corresponding figures from other economies before. According to Helminen (1998, 23), for example, of all the partial factors of productivity the material productivity is one closest to eco-efficiency. Moreover, of the economic production factors, only material consumption has any direct link to the natural economy. In this study the progress of eco-efficiency in the Finnish economy is compared to the corresponding progress made by certain other industrialised countries through material efficiency. The reason for this approach is the limited availability of comparable data. This research uses the data gathered by Adriaanse et. al. (1997) on the material efficiencies of the economies of Germany, the Netherlands, the USA and Japan. These data were collected in research conducted by the Wuppertal Institute in October 1992 into material balances in industrialised countries. The World Resources Institute, the Netherlands Ministry of Housing and the Environment and the Japanese National Environmental Research Centre joined the project in April 1996. At the same time it was decided to compile comparable material flow accounts for these four countries. This work was completed in April 1997 (Bringezu 1997, 57).

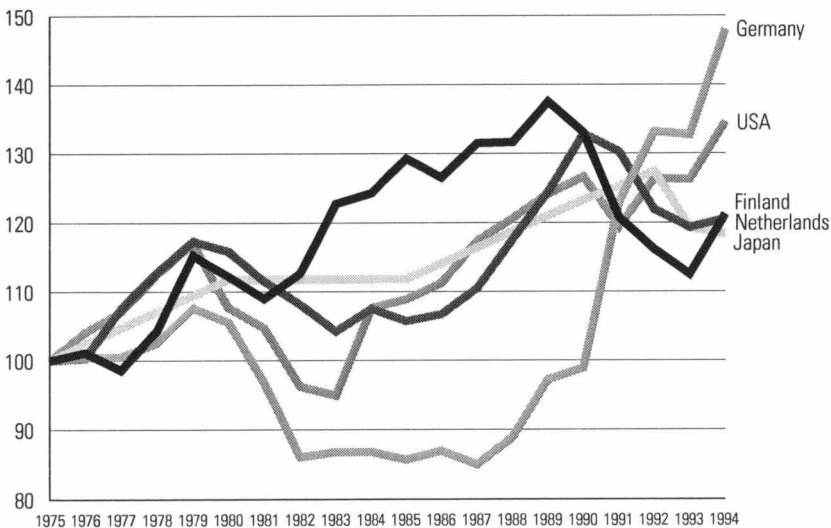
It is problematic from the point of view of study that the available international comparable data are only available up to 1994. This means that it is not yet possible to compare the recent progress made by Finland with other industrialised countries. It is also not possible to make a comparisons for the various partial factors of eco-efficiency because of deficiencies in the information base. No calculations of progress made in the EDP1 are as yet available for other industrialised countries. Moreover the data on aerial emissions and aquatic discharges are discontinuous and unsuitable for use in time series analysis. The direct material consumptions of the economies of the industrialised countries re-

viewed are shown in Table 3. The material flow data for Finland (Hoffrén 1997b, 1998a and 1998b) are the same as those used in Chapter 4. The calculations of Adriaanse et. al. describing direct consumption of materials in Germany, the USA, the Netherlands and Japan have been amended in certain respects in this study to

Table 3
Direct Material Inputs of certain industrialised countries in 1980-1994
 (million tonnes)

	Finland	Germany	Japan	USA	Netherlands
1980	156	1,017	1,842	4,872	473
1981	151	933	1,772	4,739	473
1982	162	830	1,718	4,354	473
1983	173	837	1,655	4,295	474
1984	174	837	1,708	4,871	474
1985	181	826	1,679	4,928	474
1986	179	838	1,695	5,035	483
1987	186	820	1,756	5,313	493
1988	188	857	1,869	5,459	503
1989	200	937	1,977	5,620	513
1990	193	954	2,111	5,732	522
1991	170	1,186	2,070	5,406	531
1992	166	1,285	1,937	5,721	540
1993	158	1,279	1,896	5,714	505
1994	174	1,427	1,915	6,092	501

Figure 14
Direct material consumption of certain industrialised countries in 1975-1994
 (1975=100)



render them comparable with the figures for Finland. The main changes are that the material contained in semi-finished and finished products have been left out of the figures, which does not in any way alter the level of direct materials consumption. Direct Material Input (DMI) is quantitatively greatest in the USA, amounting to more than 6 billion tonnes in 1994. The next highest consumption is in Japan and Germany.

Direct Material Input grew after 1983 in all of the countries reviewed right up to 1989-1990. After this consumption fell sharply in all countries except Germany. Evaluation of the German situation is hampered by the reunification of the country in 1990, after which the German figures also include data from the former GDR. Consumption of materials appears to have grown in 1994 in Germany, the USA and Finland. In the Netherlands and Japan, on the other hand, the fall merely seems to have stabilised at the 1993 level. The progress in direct material consumption (DMI) in Finland, the USA, Germany, the Netherlands and Japan compared to the 1980 base year is shown in Figure 14.

When evaluating the material efficiency of an economy it is initially important to understand Direct Material Input (DMI) in

Table 4
Direct material consumption of certain industrialised countries in 1980-1994

	Finland		Germany		Japan		USA		Netherlands	
	Tonnes per capita	Change-% from preceding year	Tonnes per capita	Change-% from preceding year	Tonnes per capita	Change-% from preceding year	Tonnes per capita	Change-% from preceding year	Tonnes per capita	Change-% from preceding year
1980	32.66	-	16.52	-	15.73	-	21.50	-	33.37	-
1981	31.43	-3.8	15.13	-8.4	15.03	-4.5	20.54	-4.5	33.28	-0.3
1982	33.55	+6.7	13.47	-11.0	14.47	-3.7	18.76	-8.7	33.18	-0.3
1983	35.59	+6.1	13.62	+1.2	13.85	-4.3	18.42	-1.8	33.08	-0.3
1984	35.57	-0.1	13.68	+0.4	14.20	+2.5	20.59	+11.8	32.98	-0.3
1985	36.88	+3.7	13.54	-1.0	13.88	-2.3	20.55	-0.2	32.89	-0.3
1986	36.45	-1.2	13.73	+1.4	13.93	+0.4	20.99	+2.1	33.35	+1.4
1987	38.39	+5.3	13.42	-2.3	14.37	+3.2	21.91	+4.4	33.81	+1.4
1988	38.07	-0.8	13.94	+3.9	15.23	+6.0	22.41	+2.3	34.26	+1.3
1989	40.35	+6.0	15.10	+8.3	16.05	+5.3	22.83	+1.9	34.70	+1.3
1990	38.79	-3.9	15.08	-0.2	17.08	+6.4	23.04	+0.9	35.14	+1.3
1991	33.94	-12.5	14.82	-1.7	16.69	-2.3	21.38	-7.2	35.42	+0.8
1992	32.95	-2.9	15.94	+7.5	15.56	-6.8	22.40	+4.8	35.46	+0.1
1993	31.19	+5.3	15.77	-1.0	15.19	-2.4	22.09	-1.4	33.12	-6.6
1994	34.24	-9.8	17.53	+11.2	15.31	+0.8	23.32	+5.6	32.57	-1.7

proportion to the population. From the point of view of Material Flow Analysis this materials consumption per capita indicator is an important measure. Table 4 shows the progress made in direct consumption of materials in Finland, Germany, the Netherlands, Japan and the USA over the period from 1980 to 1994 together with the annual percentage changes in order to assess the trend of progress.

The size of DMI per capita differs considerably in different countries. This is partly due to varying raw material intensity in the industries of various countries. The economies of Finland and the Netherlands, however, appear to be quite similar in this respect, both being economies which use large quantities of raw materials. In both of these countries per capita DMI is a good 30 tonnes per year. The economies of Germany and Japan are also quite similar. Per capita DMI in these countries is more than 15 tonnes per year. The USA lies between these two groups with a good 20 tonnes of material per head of population per year. The progress made by the DMI per capita indicator is also shown in Figure 15.

At the beginning of the 1980s DMI per capita fell in all other industrialised countries except Finland. At the end of the 1980s DMI per capita also began to grow in the USA, the Netherlands, Japan and Germany, even though this growth was nowhere

Figure 15
DMI per capita indicator in certain industrialised countries in 1975-1994
(1975=100)

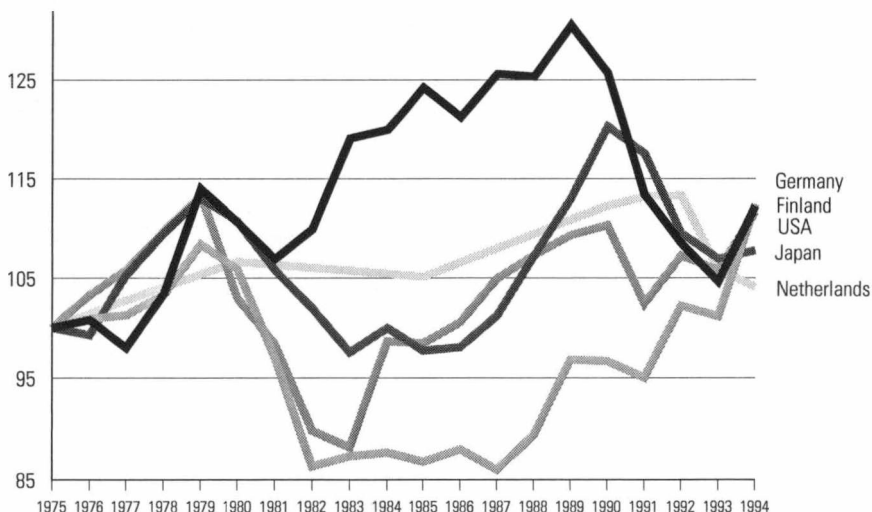


Table 5
Improvement in DMI/GDP indicator compared to 1980 in certain industrialised countries in 1981-1994 (%)

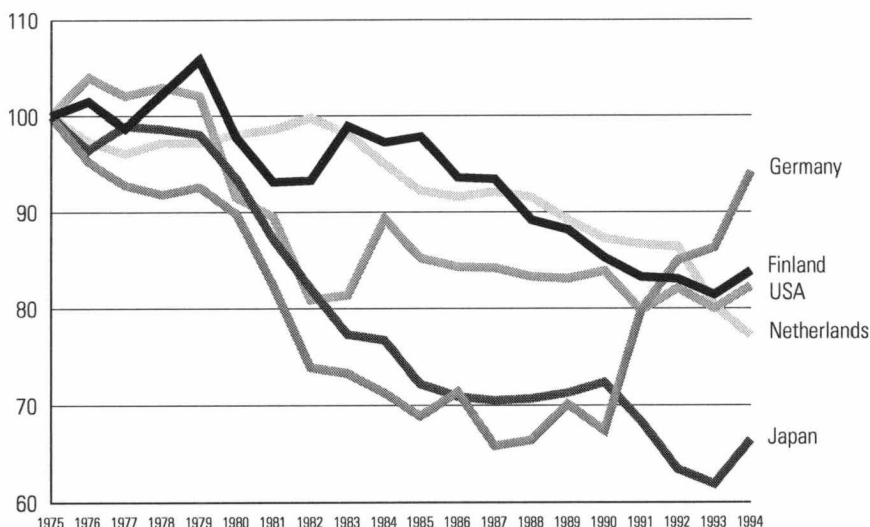
	Finland	Germany	Japan	USA	Netherlands
1981	+5.1	+8.4	+6.78	+4.4	-1.0
1982	+1.4	+17.7	+12.71	+10.2	-2.0
1983	-2.5	+20.6	+18.35	+14.8	-1.0
1984	+0.0	+20.5	+19.36	+9.0	+2.3
1985	-0.7	+23.0	+24.38	+10.7	+4.8
1986	+2.5	+23.6	+25.79	+11.4	+4.8
1987	+3.0	+26.3	+26.74	+9.3	+3.9
1988	+6.2	+25.8	+26.41	+10.3	+4.7
1989	+5.6	+21.5	+25.55	+10.7	+6.6
1990	+8.8	+24.0	+24.35	+11.7	+9.7
1991	+13.7	+23.9	+28.42	+16.0	+10.0
1992	+12.6	+19.4	+33.44	+13.3	+9.8
1993	+15.9	+18.8	+34.62	+15.2	+15.8
1994	+11.3	+11.8	+34.29	+12.4	+18.3

nearly as rapid as it was in Finland. DMI per capita reached a peak in Finland in 1989, after which it collapsed by up to 30 per cent by 1993. In the other industrialised countries DMI per capita also stabilised in 1989-1990 and then began to fall. By 1994 DMI per capita had returned to a relative level close to the 1980 level. It is worth noting that the progress of the USA, Finland and the reunified Germany was, relatively speaking, strongly convergent. Japan and the Netherlands enjoyed a slightly lower level of progress.

The material efficiency of an economy is, however, best described by the ratio of DMI to unit of GDP. For reasons of comparability, GDPs are generally stated in real terms, at the prices of some particular year. GDP data are official data of each country and the calculation of the DMI/GDP indicator in Table 5 is based on real prices from 1985 or corresponding prices from 1980.

According to Bringezu (1997, 62), the most important observation made in the research led by the Wuppertal Institute was that direct material consumption was gradually falling in all of the countries reviewed. This development has, however, been more a matter of phasing than of improvement. Bringezu proposes that generally speaking improvements in the efficiency of an economy also shows up as reduced materials consumption. As is visible in Table 5, Finland's progress has followed the same trends as the

Figure 16
DMI per unit of GDP indicator in certain industrialised countries (1980=100)



other industrialised countries reviewed. The progress made in the DMI per GDP indicator in these countries is also shown in Figure 16.

The DMI per unit of GDP indicator seems to have fallen considerably in the 1980s and begun to rise again in 1993. Unlike the other industrialised countries, the fall in the DMI per unit of GDP indicator began in Finland and the Netherlands only after 1983. Where the DMI per unit of GDP indicator fell by nearly 24 per cent in Germany and Japan by 1990, the fall in Finland was only 9.8 per cent. The DMI per unit of GDP indicator for Japan also fell after this, but that of Germany rose. Assessments of the true situation of Germany are hampered by the effects of the reunification of the country in 1990, which changed the economic structure of the country considerably in some respects. In Finland the DMI per unit of GDP indicator continued to fall until 1993, since which time it has grown slightly. By 1994 the DMI/GDP indicator for Finland had fallen by a total of 11.3 per cent of its 1980 level. The corresponding fall in Germany was 11.8 per cent, in the USA 12.4 per cent, in the Netherlands 18.3 per cent and in Japan 34.3 per cent.

Based on the actual progress made, The annual percentage falls in the DMI/GDP indicator for Finland, Germany, Japan, the USA and the Netherlands may be calculated. These annual falls are presented in Table 6.

Table 6
Reduction in use of materials in certain industrialised countries (per cent)

	Reduction over the period	Reduction over the period	Annual reduction	Annual reduction
	1980-94	1990-94	1980-94	1990-94
Japan	-34.3	-10.0	-2.29	-2.00
USA	-22.4	-0.7	-1.49	-0.14
Netherlands	-18.3	-8.6	-1.22	-1.72
Germany	-11.8	+12.2	-0.79	+2.44
Finland	-11.3	-2.5	-0.75	-0.50

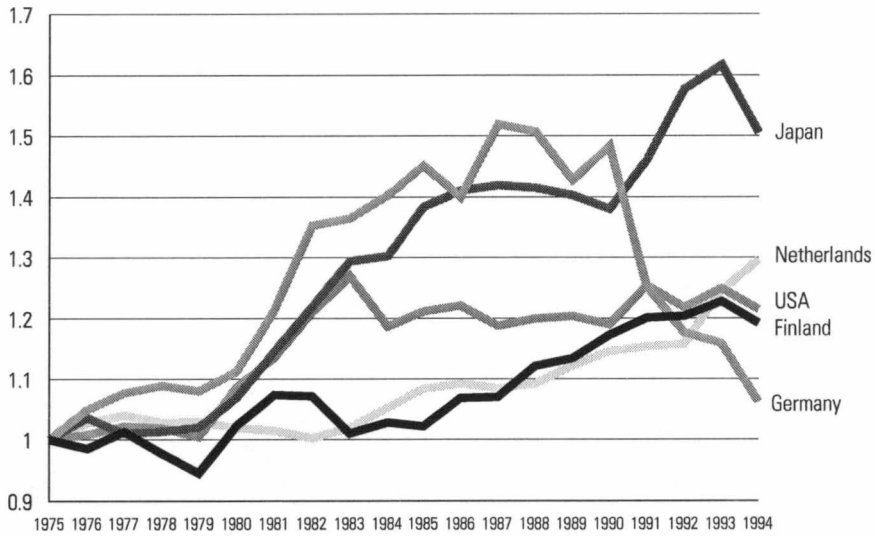
The value of the DMI/GDP indicator seems to have fallen in all of the countries examined over the 15 year period of the examination. Aside from the Netherlands, the rate of fall in the industrialised countries seems to have slowed down in the early 1990s. Achievement of the Factor 4 and 10 objectives may be estimated to require an annual improvement of 5.3 per cent in eco-efficiency. The average fall in the DMI/GDP indicators shown in the table 6 for the years 1980 to 1994 vary between 0.8 and 2.3 per cent, which is too slow a rate of progress from the point of view of the Factor objectives. In order to achieve the Factor objectives, the rate of fall in the early 21st century ought to be nearly 2.5 times the actual rate of progress which has occurred.

The material efficiencies presented in Figure 16 for the economies of Finland, Germany, the USA, Japan and the Netherlands may also be examined using the Eco-efficiency 2 measure (4.1.2) applied in Chapter 4. Welfare, however, must be measured using the ordinary Gross Domestic Product (GDP) indicator instead of the environmentally adjusted domestic product (EDP1). If this is done, then the formula (10) for Eco-efficiency 2 is as follows (see Adriaanse et. al. 1997, 14):

$$Eco\text{-}efficiency\ 2 = \frac{GDP}{L} , \quad (10)$$

where: GDP is the real Gross Domestic Product, and
 L is the primary consumption of natural resources.

Figure 17
Efficiency of economies in using materials in certain industrialised countries
in 1975-1994, (Eco-efficiency 2)



The results obtained using formula (10) are shown in Figure 17 and in statistical appendix 6 to this research report.

Figure 17 shows that direct materials consumption by the Finnish economy is converging strongly with the use of materials in other industrialised countries during the period examined. While in the 1980s Finland's situation still differed considerably from that of other industrialised countries, the structure of materials consumption in 1994 is already very similar to that of other industrialised countries.

6 CONCLUSIONS

This study has centred on an examination of the basis for a new environmental policy strategy of eco-efficiency and on analysing the eco-efficiency of the Finnish economy. Aside from the objectives of environmental policy the study also serves other objectives which are generally regarded as important in society, such as cost effectiveness and thrift. These objectives are quite strongly associated with the idea of eco-efficiency. The study is the first to make practical measurements of the progress of eco-efficiency in an economy. The welfare dimension of eco-efficiency in particular has never before in international research been the subject of such comprehensive consideration. The study also sheds new light on the material basis of the Finnish economy using indicators which have been applied in international research. No corresponding analysis of material flows in the Finnish economy has previously been performed. The information base gathered for the study will also enable the progress in Finland's eco-efficiency to be the subject of international comparison in future years.

In practice eco-efficiency seeks to combine as congruent objectives the economic and material efficiency of production systems and ecological sustainability with maintenance of at least the present level of satisfaction of needs (welfare) for future generations. The global carrying capacity imposes material limits on increases in welfare which various investigations indicate are strained by the global economy both in respect of environmental pollution and the use of natural resources. A prime objective of eco-efficiency is avoiding the environmental problems which are brought about by such production and which lead to falling standards of welfare before they arise. The greatest merit of this approach is that it will ultimately enable holistic analyses of the interaction between the environment and the economy based on research and statistical data to be performed in practice.

From the point of view of sustainable development an efficient economy is progressing along eco-efficient lines when it produces

the improvement in quality of life which it consumes using ever-lower quantities of natural resources and energy. The concept of efficiency in neoclassical economics is thus not an adequate criterion for eco-efficiency as the economy may be efficient from an economic point of view even though in practice it squanders natural resources and energy. In addition to economic efficiency, the policy of sustainable development requires production to be ecologically efficient and sustainable, socially ethical and just. Of these objectives, however, only the economic and ecological factors are measurable. Therefore the measurement of eco-efficiency on the basis of studies and research has centred on measuring the various quantifiable dimensions of sustainable development. Measuring eco-efficiency in practice is still very problematic at present. The current standard of information on the use of materials and energy at best enables general assessments to be made of progress in the material efficiency of production.

Attempts to measure the eco-efficiency of societies, production processes and products are the first concrete steps towards imposing quantitative objectives on an economy complying with the principles of sustainable development. The indicators of eco-efficiency link together output (welfare) and input (use of natural resources). The advantage of using them by comparison, for example, with the so-called "green" GDP is that while no effort need be made when compiling them to use controversial methods of setting prices on material flow tonnages, they nevertheless remain capable of providing an estimate of the direction of progress. A great deal of work still needs to be done to improve the indicators of eco-efficiency to make them suitable for use in an integrated economic and environmental policy for society. One particular problem at the moment is that of how to best measure improvements in quality of life (i.e. in welfare). To do this, an allowance must also be made in financial terms for external impacts on welfare. Eco-efficiency, however, is a good practical social action strategy when seeking to satisfy the needs of welfare in an optimum manner according to the principles of sustainable development.

While Material Flow Accounting as such provide a systematic and reliable overall picture of progress in the consumption of materials without setting prices on stocks, it is not possible, however, using overall material flow data, to use them to perform a deeper analysis of the operations of the economy nor do they assist the

compilation of predictions of technological development. This is an important defect as unwillingness to implement the reforms in patterns of production and consumption which are required by a policy of sustainable development has left technological development as the only way to avoid the ecological crisis which threatens welfare. Even though Material Flow Accounting may be used to describe the quantity of environmental impacts at the general macroeconomic level, it is not possible to use this approach to obtain a more precise picture of their detailed impacts at the micro-economic level. The reason for this is the problem of finding units of measurement, as the summation of tonnes and kilograms of various materials under a single indicator gives only a very rough picture of the state of the environment. A small amount of a highly toxic material may have a greater adverse biological impact on the environment than, for example, the use of much larger but harmless quantities of stone material for the needs of the economy. There is, indeed, a hidden idea in eco-efficiency thinking to the effect that current environmental policy instruments adequately ensure that these materials which, even in small amounts, are highly toxic or otherwise hazardous pose no threat to the environment or to human welfare. Thus the ability of various material flows to cause various environmental impacts may be neutralised by means of environmental or other social policy measures to the extent that it is possible to compile and use the DMI and TMR indicators.

Eco-efficiency examination provides environmental policy several new opportunities. By shifting attention away from traditional environmental protection and onto reducing the overall use of materials, it is possible to reduce environmental pollution considerably. Reducing the amount of material bound up in products while the level of welfare increases or remains at least stable provides many positive opportunities, not only in environmental policy but also elsewhere in society. These opportunities will be manifest in cost savings as the consumption of materials falls and new technological innovations associated with the processes of production and consumption. The idea of eco-efficiency is well suited as an instrument of environmental policy, providing an opportunity for quantitative evaluation of the pace of progress. Research findings indicate that Finland's eco-efficiency seems to have improved over the last 19 years as the use of materials and environmental impacts have fallen, both in absolute terms and in proportion to the improvements in quality of life which have been achieved. Di-

rect Material Input per capita grew from 32 tonnes in 1980 to more than 40 tonnes in 1989. After this consumption began to fall, reaching a low point of 31 tonnes in 1993. There was a slight increase in consumption at the end of the 1990s, which stood at 38 tonnes in 1998. Direct consumption of materials per unit of GDP has fallen fairly steadily from FIM 0.41 per kilogram in 1980 to FIM 0.36 per kilogram in 1998. Finland's eco-efficiency has actually improved quite substantially over the period under review and based on this review the level of welfare in Finland measured by GDP no longer seems to be tied to growth in consumption of materials in the 1990s. The Finnish economy in 1998 was over 45 per cent more eco-efficient than it was in 1980. Production efficiency appears to have increased most over the period from 1995 to 1998 thanks to more efficient use of materials and reductions in adverse environmental impacts. This is unquestionably due at least in part to the rise of the electronics sector and the status of services as sources of welfare. The progress made by Finland has been the same as that of the USA, Germany, Japan and the Netherlands. Achievement of the Factor 10 and Factor 4 objectives, however, would require, according to the eco-efficiency 2 formula, reducing the use of materials at a pace 1.7 times greater than that actually attained during the 1990s. On this outlook, the current pace of progress will not be adequate to achieve the Factor objectives. Environmental policy should give greater attention to improving the efficiency of use of environmental and natural resources.

Research into measuring the eco-efficiency of the Finnish economy is going to continue. The aim is to establish a theoretical basis for such research and to improve the measurement of eco-efficiency in practice. Further research will involve improving the current information base on welfare and the use of materials and compiling longer time series. Further research will require particular attention to be given to improving the measurement of welfare. A better indicator of welfare could be, for example, an "Index of Sustainable Economic Welfare" (ISEW) compiled for Finland. Because of the environmental impact potential associated with material flows and for the sake of international comparability, allowance should be made in eco-efficiency examinations for the so-called hidden flows involved in the material cycles of the economy whenever the available data enables this to be done. To describe consumption of materials it will also be necessary to develop a predictive model which will not only provide a better ex-

planation of the progress which has occurred but will also enable the compilation of scenarios. It would seem to be possible to compile a predictive model on the basis of the University of Tampere LINDA (= Long-range Integrated Development Analysis) energy scenario model. A model predicting consumption of materials would be particularly serviceable when evaluating achievement of the Factor objectives. It would also enable international comparisons to be made.

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APPENDIX 1

OVERALL CONSUMPTION OF PRIMARY MATERIALS

Overall consumption of primary materials in Finland 1960-1998 (million tonnes)

	Ores	Stone material*)	Fossil Fuels	Wood material	Crops	Others	Total	L-index (1980=100)
1960	5.2	43.3	5.0	43.5	9.2	2.4	108.6	-
1961	6.4	43.6	6.0	45.7	8.3	1.4	111.4	-
1962	6.7	48.8	6.6	42.1	7.7	1.6	113.5	-
1963	6.6	46.0	7.4	41.6	8.3	1.6	111.5	-
1964	7.5	57.2	8.7	42.9	7.6	1.8	125.7	-
1965	8.1	67.3	9.8	42.0	8.8	2.5	138.5	-
1966	7.9	72.6	10.8	40.5	8.4	2.3	142.5	-
1967	8.2	60.8	11.0	40.6	8.5	2.1	131.2	-
1968	9.0	65.9	12.3	40.4	8.6	2.0	138.2	-
1969	10.4	72.4	14.4	42.9	7.8	4.6	152.5	-
1970	11.3	78.0	14.3	44.2	9.2	4.6	161.6	-
1971	10.7	83.0	14.3	45.1	9.1	5.0	167.2	-
1972	12.5	79.0	16.0	54.2	9.3	5.0	176.0	-
1973	13.8	78.0	17.7	57.8	9.0	5.8	182.1	-
1974	14.5	65.0	16.2	55.6	8.7	6.3	166.3	-
1975	13.6	57.0	16.0	45.6	9.0	6.5	147.7	-
1976	14.1	55.1	18.2	44.9	10.4	6.6	149.3	-
1977	15.5	50.1	17.9	45.2	9.9	7.0	145.6	-
1978	15.3	53.0	19.3	49.2	10.2	7.0	154.0	-
1979	16.2	60.1	19.3	56.7	10.8	7.2	170.3	-
1980	18.6	62.8	19.4	45.5	10.2	9.3	165.8	100.0
1981	18.2	64.8	15.7	43.4	9.2	9.6	160.9	96.7
1982	19.2	69.6	15.2	42.1	10.9	9.4	166.4	103.7
1983	21.2	82.4	15.0	41.3	12.0	9.4	181.3	110.7
1984	21.9	80.2	15.6	43.3	11.6	11.0	183.6	111.3
1985	21.4	85.2	17.1	44.0	11.4	11.8	190.9	115.8
1986	19.3	86.8	16.4	39.5	11.8	13.1	186.9	114.8
1987	19.2	97.1	17.4	43.0	7.8	9.7	194.2	118.8
1988	20.1	92.0	17.5	45.5	9.9	9.4	194.4	120.6
1989	19.8	97.4	17.2	47.0	11.4	10.3	203.1	128.3
1990	19.7	93.4	17.1	44.0	11.8	10.5	196.5	123.9
1991	18.1	85.4	16.7	36.0	10.8	11.0	178.3	109.0
1992	17.3	75.4	15.8	41.7	9.8	9.3	171.6	106.4
1993	17.8	66.4	15.9	43.7	11.5	10.7	166.2	101.2
1994	17.9	68.4	17.8	50.9	10.6	13.1	179.0	111.6
1995	16.0	69.4	16.0	54.4	12.1	12.1	180.3	111.4
1996	16.4	65.4	17.9	47.1	12.2	13.5	172.7	106.5
1997	17.2	70.4	16.2	58.1	12.6	12.8	187.6	116.1
1998	17.3	75.4	16.0	60.0	12.0	17.0	197.7	119.2

*) = estimate.

Classification: **Ores:** domestic quarrying of ores, lime and industrial minerals; quantity of extracted utility stone, **Stone material:** quantity of extracted domestic sand and gravel, quantity of crushed gravel and rock, and clay, **Fossil fuels:** total consumption of oil, coal and coke, **Timber:** quantity of domestic net fellings and imported timber, **Crops:** quantity of field crops and other cultivated plants, **Others:** imports of metals, peat extraction, garden production, forestry by-products and fishing catches.

Sources: **Ores:** Mining Industry Association, Vuorimies-magazine. **Stone material:** Geological Survey of Finland, Finnish National Road Administration and Confederation of Finnish Earth Constructors. **Clay:** Geological Survey of Finland. **Imported metals and materials:** Metal and Engineering Industry Annual Reports. **Fossil fuels:** Statistics Finland: Energy Statistics 1996. **Timber resources and forestry by-products:** Institute of Forestry Research, statistical yearbooks of forests. **Peat:** Peat Industry Association and Statistical Yearbooks of Forests. **Crops:** Ministry of Agriculture and Forestry, statistical yearbooks of agriculture. **Others:** Research Publications of the Institute of Fisheries and Game.

APPENDIX 2

PROGRESS OF FINNISH ECONOMY INDICATORS

Gross Domestic Product and Net Domestic Product 1975-1998 (FIM million)

	GDP, cp	GDP, rp	GDP-index	NDP, cp
1975	103,174	330,360	100.0	87,173
1976	116,644	328,958	99.6	98,025
1977	128,545	329,764	99.8	106,663
1978	142,289	336,667	101.9	161,421
1979	165,550	360,092	109.0	138,266
1980	191,376	379,294	114.8	159,791
1981	216,660	386,361	117.0	179,613
1982	243,585	398,907	120.7	201,656
1983	271,607	409,690	124.0	224,243
1984	304,597	422,048	127.8	252,918
1985	331,628	436,258	132.1	276,122
1986	354,994	446,606	135.2	295,411
1987	386,855	464,917	140.7	322,088
1988	434,341	487,719	147.6	362,885
1989	486,998	515,364	156.0	402,872
1990	515,430	515,430	156.0	420,878
1991	490,868	479,011	145.0	389,129
1992	476,778	462,003	139.8	370,075
1993	482,397	456,571	138.2	368,815
1994	510,992	477,340	144.5	402,086
1995	549,863	501,490	151.8	440,794
1996	574,027	519,322	157.2	466,103
1997	622,106	550,532	166.6	513,556
1998*)	652,589	566,729	171.5	539,283

cp = current prices.

rp = real prices, given here at 1990 prices.

*) = estimation in accordance with the SNA-68 recommendation.

Environmentally adjusted domestic product EDP1 and EDP2 (FIM million)

	EDP1, cp	EDP1, rp	RE -index	EDP2, rp
1980	158,533	314,201	100.0	277,312
1981	178,614	318,515	101.4	289,507
1982	200,663	328,616	104.6	303,745
1983	223,538	337,183	107.3	317,103
1984	251,787	348,875	111.0	330,269
1985	274,911	361,656	115.1	344,453
1986	294,467	370,478	117.9	353,426
1987	320,727	385,466	122.7	370,038
1988	361,113	405,490	129.1	390,239
1989	399,954	423,271	134.7	409,597
1990	417,836	417,834	133.0	405,413
1991	386,786	377,465	120.1	365,052
1992	364,371	352,896	112.3	341,575
1993	362,830	342,530	109.0	332,313
1994	396,119	369,638	117.6	358,577
1995	432,998	394,683	125.6	384,444
1996	458,561	414,541	131.9	403,427
1997	505,257	454,432	144.6	443,802
1998*)	530,808	460,971	146.7	451,183

cp = current prices.

rp = real prices, given here at 1990 prices.

*) = estimation in accordance with the SNA-68 recommendation.

Sources: **GDP and NDP**: Statistics Finland, System of National Accounts. **EDP**: Hoffrén 1997a and 1998b and Appendix 3 to this report.

APPENDIX 3

FINLAND'S ENVIRONMENTAL PROTECTION COSTS

Finland's environmental protection costs 1980-1998 (FIM million, current prices)

	State	Transfers	Municipalities	Industry	NGO's	Total
1980	163	-37	1,536	340	..	2,002
1981	199	-42	1,661	340	..	2,158
1982	231	-53	1,764	510	..	2,452
1983	251	-53	1,748	435	..	2,381
1984	304	-57	2,153	395	..	2,795
1985	399	-60	2,299	1,035	..	3,673
1986	435	-53	2,396	1,049	..	3,827
1987	536	-50	2,535	910	..	3,931
1988	480	-28	2,625	1,269	..	4,346
1989	684	-53	2,937	1,647	..	5,215
1990	639	-31	3,408	1,935	7	5,958
1991	929	-72	3,610	1,682	11	6,160
1992	1,694	-58	3,549	3,196	14	8,395
1993	1,687	-79	4,299	3,124	14	8,975
1994	1,977	-80	3,472	2,512	14	7,895
1995	3,227	-37	3,245	3,113	15	9,563
1996	3,726	-54	3,206	3,418	15*)	10,311
1997	4,141	-68	3,411	3,327	15*)	10,826
1998	4,425	-51	3,263	3,350	15*)	11,002

NB.

Classification: **State:** environmental administration, environmental cooperation in Central and Eastern Europe, environmental protection and nature conservation, environmental research, environmental costs in agriculture and energy saving costs. **Transfers** comprise various transfers of funds such as grants and subsidies to municipalities and enterprises. **Municipalities:** Sewerage, waste water treatment, solid waste and environmental management costs. Municipal air protection costs of energy management are included in the figures for industry. **Industry:** 1980-1984: industrial water protection costs only, 1985-87: water protection costs and environmental protection costs of the forest industry sector, 1988-1991: water protection costs, environmental protection costs of the forest and chemical industry sectors and 1992-1995: all industrial environmental protection costs. **NGO's:** Salary costs of environmental organisations.

.. = no data available.

*) = forecast.

Sources: Hoffrén 1997a, 129 and 1999, 9, 12.

APPENDIX 4. PROGRESS OF THE MAIN ENVIRONMENTAL IMPACTS IN FINLAND

Finnish sulphur dioxide (SO₂), nitrogen oxide (NO_x) and carbon dioxide (CO₂) emissions 1980-1998 (thousand tonnes)

	SO ₂	NO _x	CO ₂	IP -index (1980=100)
1980	584	295	54,000	100.0
1981	534	276	45,000	83.5
1982	484	271	43,000	79.7
1983	372	262	43,000	79.5
1984	368	258	44,000	81.3
1985	383	275	50,000	92.3
1986	331	278	49,000	90.4
1987	327	288	52,000	95.9
1988	303	293	52,000	95.9
1989	242	301	52,000	99.4
1990	258	300	54,000	97.6
1991	195	290	53,000	95.6
1992	141	284	52,000	95.5
1993	122	282	52,000	95.5
1994	115	282	58,000	106.4
1995	96	258	55,000	100.9
1996	105	268	62,000	113.7
1997	100	260	59,000	108.2
1998	96*)	260*)	56,000	102.7

Source: Hoffrén 1998b, 49.

*) = forecast.

NB.

These figures exclude emissions from foreign transport. Carbon dioxide emissions comprise emissions from fossil fuels and peat, sulphur dioxide emissions are sulphurous emissions from energy generation expressed as sulphur dioxide and nitrogen oxide emissions are nitrogenous emissions from industry and energy generation expressed as nitrogen oxides.

Finland's aquatic discharges of phosphorus and nitrogen 1980-1997

	Phosphorus discharges to water		Nitrogen discharges to water		VP-index
	Tonnes	(1980=100)	Tonnes	(1980=100)	(1980=100)
1980	1,622	100.0	20,874	100.0	100.0
1981	1,550	95.5	20,793	99.6	97.6
1982	1,477	91.1	20,712	99.2	95.1
1983	1,474	90.9	21,109	101.1	96.0
1984	1,471	90.7	21,505	103.0	96.9
1985	1,488	91.7	21,947	105.1	99.4
1986	1,407	86.7	21,163	101.4	94.1
1987	1,489	91.8	21,856	104.7	98.3
1988	1,549	95.5	22,161	106.2	100.8
1989	1,518	93.6	22,580	108.2	100.9
1990	1,407	86.7	22,745	109.0	97.9
1991	1,119	69.0	21,888	104.9	86.9
1992	999	61.6	21,093	101.0	81.3
1993	844	52.0	20,306	97.3	74.7
1994	820	50.6	20,307	97.3	73.4
1995	756	46.6	20,080	96.2	71.4
1996	697	43.0	19,315	92.5	67.8
1997	640	39.5	18,780	90.0	64.8

Source: Finnish Environment Institute.

APPENDIX 5. PROGRESS OF ECO-EFFICIENCY IN FINLAND

Values of indices used in measuring eco-efficiency 1980-1998 (1980=100)

	RE	L	IP	VP	V
1980	100.0	100.0	100.0	100.0	100.0
1981	101.4	96.7	83.5	97.6	90.5
1982	104.6	103.7	79.7	95.1	87.4
1983	107.3	110.7	79.5	96.0	87.8
1984	111.0	111.3	81.3	96.9	89.1
1985	115.1	115.8	92.3	98.4	95.4
1986	117.9	114.8	90.4	94.1	92.2
1987	122.7	118.8	95.9	98.3	97.1
1988	129.1	120.6	95.8	100.8	98.3
1989	134.7	126.7	99.4	100.9	100.1
1990	133.0	122.4	97.6	97.9	97.7
1991	120.1	109.0	95.6	86.9	91.3
1992	112.4	106.4	95.5	81.3	88.4
1993	109.3	101.2	95.5	74.7	85.1
1994	117.8	111.6	106.4	73.4	89.9
1995	125.7	111.4	100.9	71.4	86.2
1996	132.0	106.5	113.7	67.8	90.8
1997	142.3	116.2	108.2	64.8	86.5
1998	146.7	118.2	102.7	64.8	83.8

Values for eco-efficiencies 1, 2, 3, 4 and 5 in 1980-1998

	Eco-efficiency 1	Eco-efficiency 2	Eco-efficiency 3	Eco-efficiency 4	Eco-efficiency 5
1980	1.00	1.00	1.00	1.00	1.00
1981	1.08	1.05	1.12	1.21	0.86
1982	1.09	1.01	1.20	1.31	0.84
1983	1.08	0.97	1.22	1.35	0.83
1984	1.11	1.00	1.25	1.37	0.84
1985	1.09	0.99	1.21	1.25	0.94
1986	1.14	1.03	1.28	1.30	0.96
1987	1.14	1.03	1.26	1.28	0.98
1988	1.18	1.07	1.31	1.35	0.95
1989	1.19	1.06	1.35	1.36	0.99
1990	1.21	1.09	1.36	1.36	1.00
1991	1.20	1.10	1.32	1.26	1.10
1992	1.15	1.06	1.27	1.18	1.17
1993	1.17	1.08	1.28	1.14	1.28
1994	1.17	1.05	1.31	1.11	1.45
1995	1.27	1.13	1.46	1.24	1.41
1996	1.34	1.24	1.45	1.16	1.68
1997	1.42	1.24	1.67	1.34	1.67
1998	1.45	1.24	1.75	1.43	1.58

APPENDIX 6. ECO-EFFICIENCIES OF ECONOMIES

**Development of GDP according to the SNA-68 recommendation in Finland,
Germany, Japan, USA and the Netherlands at 1990 price level 1975-1994**

	Finland	Germany	Japan	USA	Netherlands
	Million	Million	Billion	Billion	Million
	FIM	DEM	JPY	USD	NLG
1975	330,360	1,654,231	234,489	3,671.5	365,448
1976	328,958	1,742,304	243,809	3,850.5	384,157
1977	329,764	1,791,875	254,513	4,014.6	398,060
1978	336,667	1,845,585	267,931	4,213.6	402,330
1979	360,092	1,923,551	280,625	4,319.4	411,290
1980	379,294	1,942,417	290,588	4,294.5	416,250
1981	386,361	1,944,342	299,801	4,367.0	414,140
1982	398,907	1,926,054	308,966	4,278.5	409,320
1983	409,690	1,959,935	316,141	4,424.3	416,320
1984	422,048	2,015,089	328,525	4,691.9	430,010
1985	436,258	2,055,997	342,993	4,845.9	443,250
1986	446,606	2,014,221	352,924	4,987.1	455,460
1987	464,917	2,135,311	367,602	5,121.3	461,900
1988	487,719	2,214,817	390,375	5,314.3	473,980
1989	515,364	2,295,094	409,235	5,489.1	496,160
1990	515,430	2,426,000	430,040	5,554.1	516,550
1991	479,011	2,548,782	446,372	5,498.5	528,281
1992	462,003	2,593,387	450,933	5,653.2	538,981
1993	456,571	2,542,853	452,339	5,790.4	543,086
1994	477,340	2,599,354	425,300	6,004.5	560,588

Source: OECD. National Accounts Main Aggregates 1960-97. Paris 1999.

Efficiencies of economies in use of materials 1975-1994 (Eco-efficiency 2)

	Finland	Germany	Japan	USA	Netherlands
1975	1.00	1.00	1.00	1.00	1.00
1976	0.99	1.05	1.04	1.01	1.03
1977	1.01	1.08	1.01	1.02	1.04
1978	0.98	1.09	1.01	1.02	1.03
1979	0.95	1.08	1.02	1.00	1.03
1980	1.02	1.11	1.07	1.09	1.02
1981	1.07	1.21	1.15	1.14	1.01
1982	1.07	1.35	1.22	1.21	1.00
1983	1.01	1.37	1.29	1.27	1.02
1984	1.03	1.40	1.30	1.19	1.05
1985	1.02	1.45	1.38	1.21	1.08
1986	1.07	1.40	1.41	1.22	1.09
1987	1.07	1.52	1.42	1.19	1.09
1988	1.12	1.51	1.42	1.20	1.09
1989	1.13	1.43	1.40	1.20	1.12
1990	1.17	1.48	1.38	1.19	1.15
1991	1.20	1.25	1.46	1.25	1.15
1992	1.20	1.18	1.58	1.22	1.16
1993	1.23	1.16	1.62	1.25	1.25
1994	1.19	1.06	1.51	1.22	1.30

PRINCIPAL CONCEPTS

Direct Material Input, DMI = A global economic indicator developed by the German Wuppertal Institute and describing in tonnes the total amount of natural resources contained in commodities produced. Using this indicator it is possible to evaluate progress in the material intensity of a national economy, the introduction of more efficient production technology and achievement of the Factor objectives.

Eco-efficiency = a social action strategy seeking to reduce the use of materials in the economy in order to reduce adverse environmental impacts. Ever smaller amounts of materials have to produce a comparatively greater amount of welfare which is more equitably distributed. The general objective of eco-efficiency is to produce "more from less" (this is known as qualitative growth).

Ecological rucksack = a concept used to express the total amount of primary material and energy which is demanded by a given product over its entire life span. This describes the quantity of primary material required by the product during its manufacture, life span and consumption.

Ecologically Sustainable Development = A strict definition of a sustainable development policy, seeking to ensure the welfare of the natural environment under all circumstances. The underlying principle is that no other commodity can replace the natural environment. This is the most common definition of sustainable development in use.

Environmental Accounting = a system of accounts which allows for natural resources, the quality of the ecosystem and human environmental impacts. Natural resource and material flow accounts provide the environmental base data for environmental accounting, which then seeks to express these in monetary terms or using indicators. Environmental accounting provides society with a comprehensive picture of the condition of its natural environment and enables calculation of an environmentally adjusted the Gross Domestic Product known as the green GDP. The United Nations issued instructions on compiling Environmental Accounts in accordance with SEEA in 1993.

Environmental Space = the maximum total annual consumption of natural resources to which each human being is “entitled” within the constraints imposed by the carrying capacity of the natural environment.

Factor 10 = an objective whereby in the long term, over the next 30 to 50 years, the investment of natural resources, raw materials and energy in each unit of production is to be reduced to one tenth of its current level. This objective is derived from the targets for reducing carbon dioxide emissions to a sustainable level.

Factor 4 = an objective whereby in the medium term, over the next 20 to 30 years, the investment of natural resources, raw materials and energy in each unit of production is to be reduced to one quarter of its current level. This objective is derived from the targets for reducing carbon dioxide emissions to a sustainable level.

Gross Domestic Product, GDP = the most important indicator of a national economy, expressing the scope of economic activity in monetary terms.

Material Flow Accounting, MFA = a systematically organised monitoring arrangement for the national economy which is based on accounts and describes the total amounts of materials and mainly fossil energy sources which are taken up by the economy, i.e. material flows. Material Flow Accounts may also be compiled when the size of stocks of natural resources are not precisely known. This enables monitoring of such aspects as overall consumption of natural resources and the associated material movements known as hidden flows, as well as calculation of the DMI and TMI indicators.

Material Flow Analysis, MFA = a method of evaluating the efficiency of use of materials using the information provided by Material Flow Accounting. Material Flow Analysis facilitates recognition of waste of natural resources and other materials in the economy which would otherwise go largely unnoticed in purely economic monitoring systems.

Material Input Per Service, MIPS = a unit of measurement developed by the German Wuppertal Institute, whereby the material intensity of various products and services in relation to a single unit of commodity produced may be monitored. This mode of monitoring is called MAIA (Material Intensity Analysis).

Natural Resource Accounting, NRA = a systematically organised social monitoring arrangement based on accounts and

describing in physical terms (such as tonnes) the size and exploitation of stocks of natural resources which are valuable and limited from an economic point of view.

System of integrated Environmental and Economic Accounts, SEEA = A system of environmental accounts which seeks to supplement the System of National Accounts with the most precise assessments of the environment and of natural resources. The United Nations issued instructions on compiling Environmental Accounts in accordance with SEEA in 1993.

System of National Accounts, SNA = a systematically organised social monitoring arrangement based on accounts and describing economic activity in monetary terms. Based on the macroeconomic theory developed in the 1930s and 1940s. The principal accounting indicator is Gross Domestic Product (GDP), which describes the scope of economic activity in monetary terms.

Total Material Input, TMI or Total Material Requirement = a global economic indicator developed by the German Wuppertal Institute, expressing in tonnes not only the amount of natural resources contained in the commodities produced by the economy but also the associated additional amounts of materials known as hidden flows. These material flows which remain outside the economic system include the wood materials (branches, needles, leaves and roots) which are not exploited in tree felling operations, the additional, unused stone extracted along with the ore in mining and quarrying, the earthworks needed for constructing technical systems (roads and settlements) and the erosion caused by human activities (such as intensive agriculture). The TMI indicator may be used to evaluate the eco-efficiency of a national economy and achievement of the Factor objectives.

Welfare = a term from economic theory denoting an improvement in the quality of life arising through satisfying the needs of individuals. According to the theory of welfare total human welfare comprises commodities produced by the economy, free commodities produced by the natural environment and leisure time.

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