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Measuring the Eco-efficiency of Welfare Generation in a National Economy

The Case of Finland

ACADEMIC DISSERTATION

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Foreword

This doctoral thesis examines the foundations of the new environmental policy strategy of eco-efficiency introduced in the 1990s and the possibilities for further development of eco-efficiency measures into guiding indicators of sustainable development for societies. The objective of the thesis is to make an eco-efficiency analysis on the basis of the available indicators and, furthermore, to develop new methods and tools for analysing the eco-efficiency of national economies.

In principle, eco-efficiency seeks to combine in practice the economic and material efficiency of production systems and ecological sustainability and, at the same time, ensure retention of a sustainable level no lower than the one that currently exists for satisfying human needs (or welfare). According to various studies, the world economy is approaching, or has even exceeded, some of its limits in respect of both environmental pollution and exhaustion of natural resources. The prime objective of eco-efficiency is advance avoidance of the environmental hazards that are caused by production and eventually lead to decreased welfare.

My thesis project has been supervised 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 Professor Raimo Lovio, Ph.D. (Econ.), of the Helsinki School of Economics and Business Administration, Research Professor Matti Melanen, Ph.D. (Tech.), of the Finnish Environment Institute, Emeritus Professor Aarni Nyberg, Ph.D. (Econ.), of the Helsinki School of Economics and Business Administration, and Senior Researcher Jyrki Luukkanen, Ph.D. (Tech.), and Researcher Jari Kaivo-oja, Lic. (Adm.) of the Finland Futures Research Centre (Turku School of Economics and Business Administration). I am also deeply indebted to my numerous colleagues at Statistics Finland for their support, as well as to Aila Hanley for revising my English and to Hilkka Lehikoinen for doing the layout work. My most special thanks go to my family, especially to my parents, Arto and Tuovi Hoffrén, for their encouragement to embark on this thesis.

My sincere hope is that this study will assist in the implementation of a policy of sustainable development in Finland and also help to promote Finnish and international research and further expansion of our knowledge in this area.

Helsinki, October 2001

Jukka Hoffrén

Contents

Abstract

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The study examines the new concept of eco-efficiency, which combines sparing use of natural resources and environmental policy objectives with economic efficiency, the aim being reduced use of natural resources in order to alleviate the environmental consequences from overburdening of the environment. Thus, it would seem a potential action strategy for the strive toward sustainable development. The policy of sustainable development requires that the economic, social and environmental dimensions of the development should be taken into account. One of the publicised quantitative goals of sustainable development is attainment of the Factor 4 target, i.e. 75 per cent reduction in materials use, and maintenance of a level of welfare at least at the current one during the next 20–30 years. This study is, for its part, a response to the need to develop suitable quantitative tools for an economy on the road to sustainable society. Finnish data have been utilised in the empirical analyses in this study in order to comprehensively assess the usefulness of eco-efficiency to an industrialised economy. The analyses reveal very promising trends as to the future achievement of eco-efficient development in Finland. I also used the eco-efficiency analysis to assess the performance of several other industrial economies.

Practical applications of the eco-efficiency analysis provide many new insights into the physical basis of a society and the welfare generation processes of western societies. Since no pricing of natural assets is needed in the actual eco-efficiency analysis, the problems of artificial pricing methods and practices can largely be avoided. In this study Gross Domestic Product (GDP), Environmentally adjusted Domestic Product (EDP1), Index of Sustainable Economic Welfare (ISEW) and Human Development Indicator (HDI) as well as the Genuine Progress Indicator (GPI) have been used as measurable proxies of welfare. As denominator of the eco-efficiency formulas I used the Direct Material Flow (DMF) measure which is a highly aggregated and rough background indicator of all the materials used in the economic activities of a society. The environmental deterioration potential of the Finnish economy is fixed to the DMF. A better aggregate measure of the gains achieved through production activities has been designed which will concentrate on forming an overall picture of the wealth generated and bypass the social policy problems of income distribution, taxation and social

welfare subsidies. This new Sustainable net Benefit Measure of production, or SBM for short, is based less on the "true" value of the production activities of the society than on the external effects caused, and could also be interpreted as "potential welfare". The SBM shows a trend of almost constant flow of economic welfare until 1995, whereafter SBM per capita takes a sharp turn upwards. The SBM and ISEW show somewhat convergent developments in 1960–1966 and in 1997–1999. Starting from the early 1970s and throughout the 1980s and early 1990s, the redistribution of welfare, implemented through political decisions, raised the ISEW to far above the level of the SBM, where it remained until the late 1980s. Future developments could be characterised by stating that any improvements in eco-efficiency will originate from increase in welfare, whereas the material input and the DMF will remain relatively stable. However, it should be remembered that further technological developments and improvements in materials use efficiency are excluded from these scenarios. The continuos technological improvements allowed for in these scenarios may well prove too modest and the actual progress remains to be seen.

The projection for the Eco-efficiency 6 measure (SBM/DMF ratio) up to 2025, based on past development, suggests the achievement of the Factor 4 targets by 2020–2030. This is thanks to the positive development of welfare (measured through the SBM indicator) accomplished during the 1990s. Whether this is a real turning point in history, or only a short-term adjustment, remains to be seen since, for example, Eco-efficiency 2 (EDP1/DMF ratio) will only be reached half way toward the target. However, these measures give a more optimistic picture of the future than do Eco-efficiency 1 (GDP/DMF ratio), Eco-efficiency 2 (EDP1/DMF ratio), Eco-efficiency 3 (ISEW/DMF ratio) or Eco-efficiency 4 (HDI/DMF ratio). A gradual decline in the DMF and a steady reduction in environmental hazards explain the trend in Eco-efficiency 6. If the desire is to measure the eco-efficiency or materials efficiency of actual production processes, the SBM is a far better measure of welfare than the GDP, EDP, HDI or ISEW are. However, it excludes the progress of the third dimension of eco-efficiency, i.e. equitable welfare, justice and ethics, from the analysis, whereas the ISEW and HDI measures take it partially into consideration. Thus, the selection of the welfare indicator determines to a large extent the eco-efficiency findings of this study. To summarise, if we wish to measure the eco-efficiency of an actual production process or the materials efficiency of production processes, the SBM is the best measurement of welfare. If the desire is to also include in an eco-efficiency analysis the progress of the third dimension of eco-efficiency, i.e. equitable welfare, justice and ethics, then the ISEW and HDI are

more useful measures of the actual welfare, or well-being, received by individuals.

From the environmental policy point of view the very essence of eco-efficiency thinking is to achieve a reduction in the use of materials. Several conclusions can also be drawn concerning achievement of the Factor 4 target in Finland by 2025. The current trends of development suggest that the Factor 4 target can be reached by 2025 without further actions targeted toward improving the eco-efficiency of Finnish economy. However, the third dimension of eco-efficiency, i.e. the equitable welfare, justice and ethics goals, call for political actions for more even and fair income distribution. The further actions could include improvements in production technologies and environmental policy actions aimed at reductions in the use of materials. Obviously, the most efficient policy would be a mix of all these actions.

Keywords: *Eco-efficiency, Dematerialisation, Measurement of welfare, Industrial metabolism, Material Flow Analysis.*

Abbreviations

AOX	Organic Chlorine Compounds
BCSD	Business Council for Sustainable Development
BEA	Bureau of Economic Analyses (United States)
BOD_7	Biological Oxygen Demand
COD	Chemical Oxygen Demand
CO_2	Carbon dioxide
cp	Current Prices
CFC	Chlorofluorocarbon
CSD	Commission on Sustainable Development
DfE	Design for Environment
DHF	Domestic Hidden Flows
DMF	Direct Material Flow
DMI	Direct Material Input
DMU	Direct Material Use
DPO	Domestic Processed Output
EAW	Economic Aspects of Welfare
ECE	Economic Commission for Europe (United Nations)
EDP	Environmentally adjusted net Domestic Product
EEEI	European Eco-Efficiency Initiative
EER	Eco-Efficiency Rate
EE1	Eco-efficiency 1 measure
EE2	Eco-efficiency 2 measure
EE3	Eco-efficiency 3 measure
EE4	Eco-efficiency 4 measure
EE5	Eco-efficiency 5 measure
EE6	Eco-efficiency 6 measure
EF	Ecological Footprint
EFTA	European Free Trade Association
EPI	Eco-Productivity Indices (Volvo) or Environmental Performance Index (Nortel)
EPR	Extended Producer Responsibility
EPS	Environmental Priority Strategy
ETLA	The Research Institute of Finnish Economy
EU	European Union
EUR	EURO currency
FDES	Framework for the Development of Environmental Statistics
FFRI	Finnish Forest Research Institute
FIM	Finnish markka

GDI	Gender adjusted Development Indicator
GDP	Gross Domestic Product
GNI	Gross National Income
GNP	Gross National Product
GPI	Genuine Progress Indicator
HDI	Human Development Index
HF	Hidden Flow
HI	Hicksian Income
HPI	Human Progress Indicator
ISD	Indicators of Sustainable Development
ISEW	Index of Sustainable Economic Welfare
KELA	The Social Insurance Institute of Finland
LCA	Life Cycle Assessment
MoAF	Ministry of Agriculture and Forestry (Finland)
MEA	Monetary Environmental Accounting
MEB	Materials-Energy Balance
MEBSS	Materials-Energy Balances Statistical System
MEW	Measure of Economic Welfare
MFA	Material Flow Accounting and Material Flow Analysis
MI	Material Input
MIPS	Material Input Per Service
MoE	Ministry of Environment (Finland)
MoF	Ministry of Finance (Finland)
NAMEA	National Accounting Matrix with Environmental Accounts
NDP	Net Domestic Product
NGO	Non-Governmental Organisation
NNI	Net National Income
NNP	Net National Product
NNW	Net National Wealth
NO_x	Oxides of Nitrogen
NO_2	Nitrogen Dioxide
NPP	Net Primary Production
NRA	Natural Resource Accounting
NRTEE	National Round Table on Economy and Environment (Canada)
OECD	Organisation for Economic Co-operation and Development
pc	Per Capita
PCSD	President's Council for Sustainable Development (United States)
PEA	Physical Environmental Accounting
PIOT	Physical Input-Output Tables

PPP	Purchasing Power Parity
ROW	Rest Of the World
rp	Real Prices
RPI	Resource Productivity Index
SBM	Sustainable net Benefit Measure
SEEA	System of integrated Environmental and Economic Accounting
SNA	System of National Accounting
SO_2	Sulphur Dioxide
SSD	Strong Sustainable Development
SSDS	System of Social and Demographic Statistics
TDO	Total Domestic Output
TMF	Total Material Flow
TMI	Total Material Input
TMR	Total Material Requirement
UN	United Nations
UNCED	United Nations Conference for Environment and Development
UNDP	United Nations Development Programme
UNEP	United Nations Environmental Programme
UNGASS	United Nations General Assembly Special Session
UNSTAT	United Nations Statistical Office
USA	United States of America
USD	United States Dollar
VA	Value Added
VTT	Technical Research Centre of Finland
WBCSD	World Business Council for Sustainable Development
WCED	World Commission on Environment and Development
WICE	World Industry Council for the Environment
WSD	Weak Sustainable Development

Concepts

Dematerialization
Dematerialization refers to the absolute or relative reduction in the quantity of materials used and/or the quantity of waste generated in the production of a unit of economic output.

Direct Material Flow, DMF
This is an overall economic indicator which describes, in terms of total tonnage, the amount of natural resources contained in the commodities produced by the economy. The indicator can be used to assess improvements in the material intensiveness of a national economy, introduction of more efficient production technologies and achievement of the Factor objectives.

Eco-efficiency
A social action strategy which seeks to reduce the use of materials in the economy in order to reduce undesirable environmental impacts. Ever smaller quantities of materials have to produce a relatively higher degree of economic affluence which is more fairly distributed. The general objective of eco-efficiency is to “get more from less” (this is also known as qualitative growth).

Ecologically sustainable development
The strictest definition of sustainable development policy goal, seeking to conserve the well-being of the natural environment under all circumstances. It is axiomatic here that the natural capital (or environment) cannot be replaced by any other commodity. This is the most common definition of sustainable development.

Ecological Economics
The ecological economics school of thought, a branch of economics, has since the late 1960s concentrated on the understanding, modelling and explaining of global environmental problems like scarcity of natural resources, exponential population growth, growing environmental problems and failures in the maximisation of society‘s total welfare, which have remained neglected issues in mainstream economics. Ecological economics advocates for the strong sustainable development i.e. that natural capital cannot be replaced by human-made capital and the reproduction capacity of global ecosystems must be ensured.

Ecological Footprint
The ecological footprint measure is a measure of the use of the ecological productive capacity. In ecological footprint analysis the actual commodities received by one member of a society are converted to the productive land area needed to produce it. This figure can be compared to the available productive land area per capita of the society.

Ecological rucksack

The material and energy inputs required for a particular product over its entire life cycle that remain hidden from the consumer.

Environmentally adjusted Domestic Product, EDP

EDP is the environmentally adjusted aggregate measure of the conventional SNA supplemented by SEEA environmental accounts. In EDP1 net growth of natural assets are added to and environmental expenditures are deducted from conventional NNI measure (NNI is the GDP minus incomes from ROW and consumption of fixed capital). The EDP2 measure can be calculated by deducting the value of other changes in environmental assets from EDP1.

Environmental accounting

A system of accounting which gathers the relevant statistical data of natural resources, the quality of ecosystems and human environmental impacts in a systematic manner. Natural resource and material flow accounting provide an environmental information basis for environmental accounting which seeks to express this information in financial terms and by using indicators. The system furnishes society with a comprehensive picture of the state of the natural environment and makes it possible to calculate gross domestic product adjusted for environmental factors, i.e. the so-called “green GDP”. In 1993, the United Nations issued instructions for the compiling of SEEA environmental accounts.

Environmental space

This concept reveals the annual total production of a productive area divided per capita to which one individual is “entitled”. In other words, this concept defines the maximum consumption of natural resources to which each individual is “entitled”, based on the capacity of the natural environment.

Green GDP

General term referring to gross domestic product (GDP) adjusted for environmental factors.

Gross Domestic Product, GDP

Gross Domestic Product (GDP) indicates the magnitude of total economic activity of an society in monetary terms by presenting the total value added produced by all institutional units resident within a country. The GDP is the primary indicator of National Accounts (SNA).

Hidden Flows, HF

Extracting or harvesting primary natural resources often requires moving or processing large quantities of materials that can modify or damage the environment even though they have no economic value. These flows are classified as hidden flows. Since there are no markets, or prices, for the hidden flows, economic accounts do not usually include them.

Human Development Index, HDI

Indicator of human development potential developed by the United Nations Environmental Programme in the 1990s. HDI includes socio-economic factors, but excludes completely the environmental factors.

Industrial Ecology

Industrial ecology views the material and energy flows of current production processes as a closed circle. The central idea is that the transformation of raw materials and energy into commodities, discharges and waste in a industrial production process is in principle parallel to that of any assimilate plant.

Industrial Metabolism

Industrial metabolism views the material and energy flows of current production processes as a closed circle. The basic idea is that the circle of energy and materials of industrial production is directly parallel to that of eco-systems. The aim of industrial metabolism studies is to gain improved knowledge and understanding of societal uses of natural resources and their total impact on the environment.

Index of Sustainable Economic Welfare, ISEW

An indicator of sustainable economic welfare developed by Herman Daly and John Cobb in 1989 to describe the economic welfare actually received by individuals. ISEW is actually based on the income distributional weighted consumption of individuals.

Factor X

This is an objective whereby the input of natural resources, raw materials and energy in each unit of production is to be reduced by factor X in order to reduce the environmental impact of economic activities accordingly, with X being between 4 and 50. There is no agreement on the specific environmental impact factor X refers to.

Factor 4

This is an objective whereby the input of natural resources, raw materials and energy in each unit of production is to be reduced to one quarter of its current level in the medium term, i.e. over the next 20 to 30 years.

Factor 10

This is an objective whereby the input of natural resources, raw materials and energy in each unit of production is to be reduced to one tenth of its current level in the long term, i.e. over the next 30 to 50 years.

Life Cycle Assessment, LCA

This is a method of assessing the environmental impacts of a product over its entire life cycle. The life cycle generally means the time between the acquisition of raw materials and energy for the manufacturing of a product and its ultimate disposal.

Material Flow Accounting, MFA

This is a monitoring system for national economies based on methodically organised accounts and denoting the total amounts of materials and mainly fossil energy sources, i.e. material flows, used in an economy. Material flow accounts can also be compiled when the sizes of the environmental or natural resource reserves are not precisely known. Material flow accounting enables the monitoring of total consumption of natural resources and the associated hidden flows, as well as calculation of the DMF and TMF indicators.

Material Flow Analysis, MFA

This is an evaluation method which assesses the efficiency of the use of materials with information from material flow accounting. Material flow analysis helps to identify the waste of natural resources and other materials in an economy, which would otherwise go unnoticed in conventional economic monitoring systems.

MIPS *(Material Input Per Service)*

This is a unit of measurement developed by the German Wuppertal Institute, whereby the material intensiveness of various products and services can be monitored in relation to a single commodity unit produced.

Natural Resource Accounting, NRA

A monitoring system based on methodically organised accounts, representing the size of economically valuable and limited reserves of natural resources and using physical quantifiers such as tonnes or cubic metres.

Social Thermodynamics

Application of thermodynamics to social sciences introduces the laws of thermodynamics into the social systems. The principles of social thermodynamics imply that the more natural resources we consume the more waste and pollution is likely to be generated as a by-product because the development of actual production technology may unavoidably lag behind the extensive economic growth.

Strong Sustainable Development, SSD

Weak sustainability requires keeping the total net investment, suitably defined to encompass all relevant forms of capital, man-made, human or natural, above or equal to zero. The very essence of strong sustainable development (SSD) is that it regards natural capital as fundamentally non-substitutable with other forms of capital. Thus, strong sustainability advocates for ecologically sustainable development that guarantees the future wellbeing of the present ecosystems.

Sustainable Development

The policy of sustainable development was introduced by WCED in 1987 to answer the problems caused by the economic growth. The aim of the policy of sustainable development is to “satisfy current needs and conserve for future generations the opportunity to satisfy their own needs”. This concept has several interpretations to practice, the most commonly known being strong and weak sustainable development.

System of National Accounting, SNA

This is an organised system of social monitoring based on methodical accounts describing the scope of activities in an economy in financial terms. Such systems are based on macroeconomic theory developed in the 1930s and 1940s. The primary indicator of the accounting is Gross Domestic Product (GDP) which indicates the magnitude of economic activity in monetary terms.

Throughput economy

The concept of the throughput economy aims to describe the very nature of current economic system. This concept is based on view that the flows of different materials that enter economy from the environment, are processed into commodities and are finally returned back at the environment as emissions and waste. (i.e. the materials and energy flow through the economy)

Total Material Flow, TMF

An overall economic indicator which describes, in terms of total tonnage, not only the amount of natural resources contained in the commodities produced by an economy, but also the hidden flows which are involved in such production. These material flows which remain outside of the economy include wood materials which are not used in logging (branches, needles, leaves and roots), earth and stone which is excavated in mining and quarrying along with usable ore and minerals, earthworks necessary in the construction of infrastructure systems (roads and communities) and erosion resulting from human activities (including intensive agriculture).

Weak Sustainable Development, WSD

Weak sustainability requires keeping the total net investment, suitably defined to encompass all relevant forms of capital, man-made, human or natural, above or equal to zero. Furthermore, weak sustainability allows the substitution of natural capital by man-made assets, provided it guarantees the current level of welfare also in the future.

1 Introduction

1.1 Description of the subject matter

The policy of sustainable development, outlined for the first time in 1987 by the United Nations, aims to provide a macro-scale solution to the growing global environmental and societal problems and failures, such as increases in pollution, waste accumulation, decreasing biodiversity, increases in population, poverty of the majority of people and inability of developing countries to develop their economies. One particular problem contributing to the growing environmental concerns is the fact that the current production systems of market societies can be economically efficient even when they squander natural resources and energy. The reason for this can be found from the inefficient functioning of the price mechanism, in particular from the current underpricing of natural resources, whereby, for example, no allowance is made in monetary terms for the pollution and waste problems caused by resource use. In fact, within the current mainstream economic school of thought, neoclassical economics, increasing environmental problems, scarcity of natural resources, exponential population growth, increasing poverty and failures in the maximisation of society‘s total welfare, are often left unsolved because of their non-existent prices.

Because of the price mechanism’s inability to translate environmental and societal phenomena into monetary terms, these issues are often bypassed in decision-making. Consequently, the current requirements of economic efficiency are not sufficient to guide productive activities to a sustainable path of development. Thus, the technologies and activities utilised today most often fail to take the so called environmental efficiency into consideration, causing more or less unintentionally environmental concerns that could have been avoided. In the 1990s, a new approach to these global problems, composed of the “dematerialisation” and “immaterialisation” processes of economies, i.e. roughly speaking of minimisation of the material throughput of economies, was introduced. Several new concepts, such as societal and industrial metabolism, ecological footprints and material flow analysis were introduced to frame the physical scale of mankind’s growing activities and to describe interactions in the economy-environment relationships. These approaches became concentrated in the eco-efficiency thinking, which aims to reduce the use of raw materials so as to reduce environmental impacts, such as pollution and waste volumes, in accordance with the principles of social thermodynamics, which imply that the more natural resources we consume the more waste and pollution is likely to be generated as a by-product because the development of actual production technology may unavoidably lag behind the extensive economic growth. Eco-efficiency thinking aims to secure a decent, equitable welfare to all individuals and, at the same time, reduce environmental degradation to a level that is sustainable.

Eco-efficiency thinking requires a totally new insight into dealings with environmental problems in science. Hinterberger et al. (1997, 4) state that although environmental science has during past decades generated a lot of knowledge which can help to understand the effects of man on the environment, it is so far incapable of predicting the effects of human actions in time and place. For example, there is no new scientific way to predict the total bouquet of the ecological consequences of releasing even a single chemical into the environment. By way of an example, it took some 15 years before CFCs were internationally recognised as ozone-destroying chemicals, and a few decades ago CO_2 was not even considered as an environmental policy issue despite the fact that the anthropogenic concentrations of this gas have been known for 180 years. Thus, this prevalence of ignorance and uncertainty suggests the need to reduce the potential of these effects as much as possible. Furthermore, Hinterberger et al. (1997, 8) argue that any mechanical material displacement causes ecological change directly – regardless of whether this material flow enters economic production or not. Environmental deterioration potential is determined not only by the harmlessness of the by-products of economic processes but also by the quantities of them that the environment must absorb. Neither are renewable resources exempted from environmental impacts, since they are usually grown on ploughed fields and are irrigated, transported and processed. Material input's ability as such to cause environmental deterioration in one form or another is the issue. Thus, from the point of material flow analysis, which focuses on the quantities of inputs, it is somewhat irrelevant whether material inputs are turned later on in economic processes into toxins, waste or emissions or not. According to Hinterberger et al. (1997, 5) toxins and other emissions must continue to bear our scrutiny. To base, as environmental administration in many cases does, "economic decisions upon recognition of critical situations is to call for the fire department, but it is not acting with concern about the future".

It is possible to arrange the economy in such a way that welfare is produced and adverse environmental consequences are minimised simultaneously. Eco-efficiency as an environmental policy concept suggests that this could be done by combining sparing use of natural resources and environmental policy objectives with economic efficiency, with the aim of reducing the volume of natural resources that are used in order to alleviate the consequences from overburdening the environment. The idea of eco-efficiency was first presented by Sturm and Schaltegger in 1990 and the idea was sustained by the World Business Council for Sustainable Development (WBCSD) which favoured the idea in its document on sustainable development at the business level in the 1992 Rio Conference. Since then, several companies have applied the eco-efficiency principles as part of their operating principles. At the moment, the WBCSD is co-organising the so called European Eco-efficiency Initiative (EEEI) to promote eco-efficiency as the leading business concept across Europe. Furthermore, the OECD, the Canadian National Round Table for Economy and Environment (NRTEE), the working group on eco-efficiency of the President's Council on Sustainable Development (PCSD) in the USA, and the Finnish Ministry of Trade and Industry's working group on eco-efficiency, among many other parties, have shown great aspirations towards eco-efficiency thinking.

An economy is progressing along eco-efficient lines when it produces improvement in the quality of life (or welfare) that is "consumed" while using ever-decreasing quantities of natural resources and energy. Because it means growing in scale, the current quantitative economic growth is not a desirable status quo, and the aim should be qualitative economic growth instead. For this reason, more efforts should be expended to foster technological innovations and changes toward less material intensive production, i.e. economic development. This way the environmental problems caused by economies could be avoided in advance. Reaching this status quo would require drafting and implementing new industrial policies. One merit of this approach is that it will ultimately facilitate practical holistic analyses that are based on research and statistical data on the interaction between the environment and the economy. Support to the idea of eco-efficiency originates from the fact that several studies show the consumption of materials exceeds the replenishment and carrying capacity of the environment, particularly in the industrialised countries (See for example Clarke (ed.) 1999).

In addition to economic efficiency, the implementation of the policy of sustainable development requires production to be ecologically efficient and sustainable, as well as socially ethical and just. Of these objectives, however, only the economic and ecological factors are measurable. Therefore, the measurement of eco-efficiency has centred on the measuring of various quantifiable dimensions of sustainable development. Measuring eco-efficiency in practice is still very problematic at present. The standard of information on the use of materials and energy has set limits to the general assessments that can be made of the progress in the materials 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 in comparison to, for example, the so called green GDP or ISEW, is that while their compiling does not involve using controversial methods of setting prices on material flow tonnages they, nevertheless, remain capable of providing an estimate of the direction of progress. One particular problem at the moment is how to measure correctly improvements in the quality of life (or well-being). GDP has its widely known shortcomings as a measure of welfare, but so have also the other measures, like EDP, HDI, ISEW and GPI. Their common feature is that they all share the same basic starting point whereby to measure welfare, an allowance must generally also be made in monetary terms for environmental impacts and deterioration.

Application of eco-efficiency at the national level provides an environmental action strategy that seems to hold much potential with regard to the global community's aspirations toward sustainable development. Eco-efficiency can be implemented at several levels: product level, company level, regional level, national level as well as global level. However, the methods of its implementation differ a lot at the different levels. The methods proven to work at one level cannot be applied to other levels direct. As a result, the theoretical foundations of eco-efficiency thinking and, especially, the measuring, explaining and forecasting techniques at the national level urgently need further development.

1.2 Objectives of the study

The main aim of my study is to search for measures to monitor the progress of eco-efficiency at a national economy level. At some level, such national monitoring should take into consideration the aspects of the major driving forces contributing to the global development and environmental problems, such as population growth, expansion of global economy and growing environmental hazards. My starting point is the idea of eco-efficiency as a potentially strategic tool of environmental policy, targeted toward seeking practical solutions for the implementation of sustainable development. In principle, the objective of the eco-efficiency approach – that is avoidance of problems resulting from quantitative growth by making qualitative improvements that reduce the relative environmental degradation potential of production and assure a "good" life to all individuals on earth – is generally supported by nearly all economists, social scientists as well as environmentalists. However, opinions about which theoretical views justify this approach and what this approach implies for environmental policy, can vary a lot. This is also true when it comes to the question of how to measure the eco-efficiency of an economy. My intention is to approach the eco-efficiency theme as an ecological economist, concentrating on the curious question of combining economic and environmental efficiency into a single measurable environmental policy approach.

My view is that reducing the use of natural resources and adjusting the structure of economic growth towards qualitative growth in accordance with sustainable development requires the development and application of a reliable measure of eco-efficiency. So far, almost no efforts have been made to develop suitable measures and indicators of eco-efficiency at the national economy level. One of my main objectives is to formulate different eco-efficiency measures and indicators that can be applied and implemented at the national economy level. In the subsequent analysis, I assess the usefulness and meaningfulness of these measures. With the empirical analyses of this study I will seek to provide an answer to the problem of how the natural resources and environmental efficiencies of the economy can be explained and how their future progress can be predicted. Subsequently, I formulate a totally new measure of welfare, the Sustainable net Benefit Measure of production (SBM), that is best suited for eco-efficiency analyses. My particular aim is to also respond to the principal question concerning the future from an environmental policy perspective: will the eco-efficiency rates required by the Factor objectives (See Concepts p. 14) be reached in Finland with the current pace of progress and, furthermore, if not, then under what conditions could it be done?

The general context of this study is to contribute to the development of practical measurement of sustainable development. Thus, the theoretical frame of reference this study leans on is located in the heart of ecological economics and as such this study utilises the methodologies of neoclassical economics, industrial ecology, social thermodynamics and practices of Keynesian national accounting. The contents of the study cover many research topics of ecological economics, e.g. material flow analysis, societal and industrial metabolism and dematerialization of production, all of which go to make up the eco-efficiency concept. The perspective and terminology of this study lie clearly in the field of economics. As a little-practised discipline in Finland, the ecological economics perspective to the environment-economy entity has not been utilised before and thus this study is among the very first in this field. Even worldwide, the eco-efficiency approach is a relatively new line of environmental policy and has been measured relatively little in practice. Therefore, I see a clear need for these kinds of analyses so that the usefulness of the eco-efficiency analysis to environmental policy needs can be assessed and, consequently, improved. My compiling of the empirical data used in this study should also be viewed as a pioneering effort. Much of the Finnish time series data that I have gathered for this study have not previously been available. Solely for the purposes of this study I have compiled for the first time Finnish time series for 1960-2000 on environmental taxes, total environmental expenditure, EDP, ISEW as well as SBM.

The main scientific offerings of this study are a review of the development of the eco-efficiency approach at the national economy level, formulation of several new eco-efficiency ratios, compilation of the relevant environmental statistical time series data presented in the Appendices, compilation of Finnish EDP and ISEW time series, empirical findings relating to the eco-efficiency analysis and formulation of the new SBM measure.

1.3 Contents of the study

This study focuses on the eco-efficiency analysis at the national economy level. I start by assessing ultimate sources of environmental concerns and welfare and principles of sustainable development and proceed to specific questions concerning eco-efficiency and its measurement. My study is largely based on the ecological economics viewpoints of the environment which, to my mind, become best condensed in eco-efficiency thinking. The main difference between me and the current environmental economics research practised in Finland is that I aim to stress the importance of holistic views, theories and analyses of the environment, society and the world. As such this research is continuation to the work I did for my licentiate thesis (see Hoffrén 1999b). The contents of this study divide into two parts: theoretical and empirical. The theoretical part comprises Chapters 2, 3 and 4. Macro-scale environmental concerns from the economics point of view are presented in Chapter 2. At first I pay attention to the overexploitation of natural capital as a basic environmental problem. I also review the consequences of global environmental concerns, as rapid economic growth and exponential population growth are reviewed in Section 2.1, together with the policy of sustainable development as a solution to these problems. The theoretical foundations of the concepts and principles relating to sustainability and qualitative growth of industrial production are subsequently outlined in Section 2.2. In Section 2.3, I present the idea and development of throughput economy thinking as well as its primary applications, together with principles of ecological economics and especially those of industrial metabolism and material flow analysis. Finally, in Section 2.4 I take a closer look at the dematerialisation of industrial economies and at the Factor targets aiming to quantify sustainability.

I examine the basis of the eco-efficiency approach, its concepts and implementation in practice in Chapter 3. At first, I review the formation and essential foundations of the eco-efficiency approach in Section 3.1. In Section 3.2, I examine the practical combining of economic efficiency and environmental efficiency into eco-efficiency. In Section 3.3, I take a close look at the methods used in measuring eco-efficiency in practice in several companies. Finally, in Section 3.4, I examine the implementation of eco-efficiency measurement at the total economy level in industrial countries. Chapter 4 concentrates on the theoretical basis of the measurement of eco-efficiency at the total economy level. First, in Section 4.1, I examine the measurement of the economic-environment efficiency of an industrial society. In Section 4.2, I present aggregated material flows as a measure of environmental stress, the main interest being in Material Flow Accounting and Material Flow Analysis (MFA). In Section 4.3, I examine the development of measuring the welfare of a society in a sustainable way. The Hicks sustainable income concept and the MEW, NNW, EAW, ISEW and NAMEA systems, among others, are examined in detail. In Section 4.4, I review the expansion of national accounts to the environment by taking a close look at the efforts made by economists to extend the existing System of National Accounts (SNA) and its GDP measure to the environment. Additionally, the SEEA system and its EDP measures are presented. Finally, in Section 4.5, I review the other social indicators of quality of life developed, including the current non-economic sustainable development indicators, i.e. the CSD and HDI indicators.

The empirical part of the study is covered by Chapters 5, 6 and 7. Chapter 5 presents the compiled data and the preliminary results of a statistical analysis of the Finnish economy. At first, in Section 5.1, I review the starting points for a practical eco-efficiency analysis at the national economy level. In Section 5.2, I present mainly the advancement of Finnish environmental drawbacks, and the concerns and counter-measures in relation to the economic development in Finland. The presented data are also used in the later empirical analysis of Finnish eco-efficiency. In Section 5.3, I review the development of various Finnish aggregate indicators, namely the conventional GDP and its derivative, the green GDP, or Environmentally adjusted Domestic Product (EDP), Direct Material Flow (DMF) and Total Material Flow (TMF), UNEP's Human Development Index (HDI), and Cobb and Daly's (1989) Index of Sustainable Economic Welfare (ISEW). I have compiled Finnish EDP and ISEW for the 1960 to 2000 time period solely for the purpose of this study. I also carry out several empirical analyses of Finnish eco-efficiency in Section 5.4 on the basis of the data presented in Sections 5.2 and 5.3. My purpose is to evaluate the applicability and usefulness of different welfare measures in eco-efficiency analyses. Section 5.5 contains a comparison between the eco-efficiency of the Finnish economy and the eco-efficiencies of the economies of Germany, Japan, the USA, the Netherlands and Sweden.

The development of eco-efficiency measures is continued in Chapter 6, by developing a new welfare measure and by assessing future developments. My main interest in Section 6.1 lies in the development of improved welfare measurements because of the severe shortcomings of the GDP, EDP, HDI and ISEW indicators revealed in Chapter 6. For this reason I have designed and compiled a totally new Sustainable net Benefit Measure of production (SBM) for Finland using the available statistical data. In Section 6.2, I analyse the dimensions of the different eco-efficiency indicators as well as draft scenarios concerning the development of Finnish eco-efficiency up to 2020–2030, i.e. the target years for reaching the Factor 4 targets. I draw and present several scenarios from different points of departure of the development of Finnish direct materials use and I review the possibilities for achieving the Factor 4 targets. In Section 6.3, I utilise the SBM measure to analyse Finnish eco-efficiency. I also make comparisons to the EDP-based eco-efficiency results obtained previously in Section 5.4. In Section 6.4, I discuss the inclusion in the analysis of the "third dimension" of eco-efficiency, namely equitable income, ethics and justice. In addition to the empirical comparisons, the Section also contains incisive discussion about the inclusion of these "third dimension" factors. Finally, the in the closing Chapter 7 of the thesis, I present the principal conclusions that can be drawn from the eco-efficiency analyses conducted in the study. My research focuses on studying its subject on the basis of literature, scientific articles and research reports, and available statistical data.

2 Macro-scale environmental problems and economics

2.1 The overexploitation of natural capital as a fundamental environmental concern

According to Haila (1999, 337) the life of humans, similar to all biological organisms, depends on the utilisation of their environment, which is changed as a result. Many researchers argue that the impact of the explosively intensifying exploitation of natural resources on the environment already exceeds the sustainable production of many environmental systems today (see, e.g., Brown et al. 1998). According to Femia et al. (1999, 4) most ecological impacts of economic activities are induced by material flows that comprise, among other things, energy carriers, minerals, fuels, sand and gravel, soil, water, air and overburdening. In principle, all masses moved by technical means cause some environmental impacts and they should be taken into account. However, all of these ecological changes included in material flows cannot be fully predicted by any scientific effort. (Femia et al. 1999, 4) The first law of thermodynamics, i.e. the principle that the amount of material and energy remains constant at any flow or process in a system, claims that the input and output of a process must be equal. This is true for materials as well as for energy flows. (Pesonen 1999, article 1:7) Matthews et al. (2000, xi) estimate that in 1996 one half to three quarters of the annual resource inputs to industrial economies are returned to the environment as wastes and pollution within a year.

To the extent that environmental impacts are the consequence of the magnitude of total material input into production in an economy, they can be lessened by reducing the use of materials e.g. by concentrating on what has been called qualitative growth. Aekerman (2000, 73) states that the concept of natural capital was first introduced in 1988 by David Pearce. According to the definition used by van Dieren (1995, 100), natural capital is basically our natural environment, and it is defined as the stock of environmentally-provided assets, such as soil, atmosphere, forests, water, and wetlands that provide a flow of useful goods or services. Natural capital also includes the sinks for wastes (assimilation service). In its conventional sense, sustainability means maintaining the environmental assets, or at least not depleting them. Undesirable environmental impacts have resulted from overexploitation of natural capital. Materials accounting systems are a means by which the stocks and appropriate flows of natural resources can be combined into a single overall picture describing their interaction. Such systems can be used to analyse changes in the natural capital. (see e.g. Aekerman 2000) For example, Hinterberger et al. (1997, 9) state that valuing this natural capital in monetary terms entails enormous difficulties because there are no right prices for goods not traded on markets and because there is no way of predicting what value the future generations would place on them.

The early classical economists of the 16th and 17th century, like Thomas Malthus and David Ricardo, were the first to take a closer theoretical look at the natural limits of economic activities. Since farmland (or natural capital by today's term) was a limited resource, it seemed to restrict population growth. Malthus focused on rapid population growth and Ricardo on the limitation of land resources. Malthus's main argument was that the increase of population would take place in geometrical sequence and farm production only in arithmetic sequence, leading the development to a dead end. However, Ricardo argued that a properly functioning price mechanism would lead to technological development that would overcome the limitation of natural capital and population increase. Neoclassical economics, born in the 1870s, adopted this belief that technological development would take place as the price mechanism deemed it necessary. Thus, until recently, population growth and scarcity of natural resources have remained marginal issues within mainstream economics. (Aekerman 2000, 39–41; Dow 1996, 54)

However, even today there is no general agreement among researchers about the belief that technological improvements driven by a properly functioning price mechanism alone would be sufficient to prevent the overexploitation of natural capital. In fact, currently the most important driving force in the expansion of global economy, contributing heavily to the growing global environmental degradation, is the exponential population growth that is taking place. According to Brown (2000, 5) the United Nations estimations suggested that the world population would increase from 2.5 billion to 6.1 billion between 1950 and 2000. Recent projections propose that the world population will go up to 8.9 billion by the year 2050. Thus, the rapid growth of the world population is set to continue. The UN further forecast that while the population of industrialised countries will in future remain at approximately the present level of 1.2 billion, that of the developing countries will rise from the present 4.8 billion to 7.7 billion. Basing on experiences from the 1950–2000 period, this population growth will inevitably increase material consumption, which is one of the main factors contributing to wellbeing, but also to environmental hazards. At present, industrialised countries consume about 75 per cent and developing countries only 25 per cent of all commodities. In fact, one of the biggest challenges facing governments in the future is how to fulfil the needs and desires of the ever increasing population, especially if and when the population of the developing countries strives to attain the consumption habits and standard of living of the industrialised countries. It seems quite obvious that the current technologies and production habits simply cannot fulfil all these desires because of finite natural resources and growing problems of pollution and waste. (e.g. see Brown 2000, 5; Brown et al. 2000, 98–99)

The United Nations' forecasts contrast the main criticisms of the neoclassical way of thinking, which claims that price mechanisms fail to function properly in respect of the natural capital, the environment and natural resources. In the industrialised countries, environmental hazards caused by economic growth brought these weaknesses of the theory to the public debate in the 1960s. One of the main critics of the neoclassical school of thought, the school of ecological economics, has since the late 1960s concentrated on the understanding, modelling and explaining of global problems like scarcity of natural resources, exponential population growth, growing environmental problems and failures in the maximisation of society‘s total welfare, which have remained neglected issues in mainstream economics. On the political arena, environmental hazards were first treated as a local problem or, as the economic theory puts it, as external effects of production. In the second phase the governments were reluctant to tackle them.

It was only in 1972 that environmental issues arrived on the agenda of global relations at the first international meeting focusing on the environment, the UN Conference on the Human Environment, which was held in Stockholm, Sweden. This progress was strengthened when the international United Nations Environmental Programme (UNEP) was established in the same year with the objective of bringing together various United Nations agencies to work for environmental protection and formulate proposals in environmental affairs. In the same year the first warning was also given in a report of the senior scientists of the Club of Rome about the scarcity of natural resources and the limits to the present kind of economic growth facing the industrialised countries. A halt to the economic growth was proposed in order to avert the catastrophe threatening humanity. Economies and the general public received a practical foretaste of the scarcity of natural resources with the first oil crisis in 1973–1975, which caused a deep recession in the world economy and subsequently triggered the industrialised countries to improve their energy efficiency.

Although the environmental problems were agglomerated in people's minds in the 1970s in an impressive way, the solutions offered by conventional economic thinking for dealing with these problems were inadequate. In the short-term the dependence of the industrialised countries on the existing production structures and technologies, combined with people's desires, effectively outlined the possibilities available to governments. In the long run the development was hampered by the reluctance and incompetence of science to give answers to these problems. For example, the dominant economic theories were becoming more and more incapable of explaining the problems facing the industrialised countries, such as growing unemployment, ever-increasing pollution and waste and inability of the developing countries to follow the path of the industrialised countries. On the other hand, the voices proposing or demanding the so called zero growth economy or "steady state" or neomalthusian policy have been conquered by people's desire to increase their economic welfare. The hope that these problems could be solved in the future was left almost totally on the shoulders of technological development.

Although no progress was achieved in the scientific field, in the political field these problems, like scarcity of resources, poverty of the developing countries, losses of biodiversity, and pollution and waste, could not be totally ignored. Consequently, the General Assembly of the United Nations established the World Commission on Environment and Development (WCED) in 1983 to provide concrete recommendations for action on the interrelated issues of environment and development, as seen from the strategic long-term viewpoint. The WCED's final report, ”Our Common Future”, in 1987 introduced the ”policy of sustainable development” to answer the problems caused by the present economic growth. The WCED also proclaimed that the policy of sustainable development must "satisfy current needs and conserve for future generations the opportunity to satisfy their own needs". This contains two key concepts: the concept of needs, in particular the essential needs of the world's poor to which overriding priority should be given; and the idea of limitations imposed by the state of technology and social organisation on the environment's ability to meet present and future needs. Thus living standards that go beyond the basic minimum are sustainable only if consumption standards everywhere have regard for long-term sustainability. (WCED 1987, 43–44)

Because by its very nature Our Common Future was a political document, the WCED appealed to the global scientific community to develop theoretical models and tools which complied with the new policy of sustainable development. The appeal of the WCED has since then been taken seriously by many scientists. The closer defining of the policy of sustainable development at the United Nations Rio de Janeiro Conference on the Environment and Development (UNCED) in summer 1992 raised the issue to the top of the research agenda of ecological economics. 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 in Rio between 178 states. The document, known as the Rio Declaration, approved by the participating countries at the end of the conference, contains a recommendation of the principles that 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 they had given in Rio.

The main achievements of the Rio process since 1992 are political agreements with very limited economic implications. At the Earth Summit in Rio the assembled world leaders signed the Framework Convention on Climate Change and the Convention on Biological Diversity endorsed the Rio Declaration and the Forest Principles and adopted Agenda 21, a plan for achieving sustainable development in the 21st century. To ensure effective follow-up of the UNCED, a Commission on Sustainable Development (CSD) was created in December 1992 to monitor and report on the implementation of the Earth Summit agreements at the local, national, regional and international levels. The most notable achievement of the Rio process so far is the international convention on the prevention of climate change, or the Kyoto protocol. This protocol, which is the first legally binding global agreement on reducing greenhouse gas emissions in the face of the threat of climate change, was concluded at the UN Climate Meeting in Kyoto, Japan, in December 1997. Under the agreement, the industrialised countries will reduce their greenhouse gas emissions by an average of 5.2 per cent from the 1990 level by the period of 2008–2012. The requirement for the United States is seven per cent, that for the EU Member States eight per cent and those for Canada and Japan six per cent. No obligations to reduce emissions were imposed on the developing countries. (See e.g. Hoffrén 1999a, 5) At the United Nations Climate Change Conference held in Bonn in July 2001 an agreement was reached on issues left open in the Kyoto Protocol – such as ground rules for the Kyoto mechanisms, carbon sinks, monitoring compliance with the Climate Convention and the financing of developing country climate projects. The United States remained outside the agreement because it saw the agreement as serving against the country's economic interests. The U.S. share of industrial country greenhouse emissions is roughly 36 per cent. The Kyoto Protocol will come into force when the industrial countries that have ratified it together account for at least 55 per cent of the industrial countries' carbon dioxide emissions levels of 1990. (Hoffrén 2001, 5)

The WCED's 14-year old appeal to the global scientists to develop theoretical models and tools that would comply with sustainable development have remained quite modest in both theoretical thinking and practice until recently. Several methods and tools to cope with the global problems have been drafted within ecological economics. Many desirable paths of development have also been outlined, but the changes required by sustainable development have not yet been implemented in practice. It has proven extremely difficult in practice to draw up agreements about a transition to sustainable development that would be based on a broad theoretical and practical consensus, or about the quantitative objectives of sustainable development. This is largely due to the political reluctance of the ruling powers to accept any changes and improvements that could harm the conventional economic development favourable to them. A policy of sustainable development based more on assumptions than facts can easily be regarded as controversial. This conclusion could be compacted to "no data, no policy", i.e. sustainable development is almost impossible to implement if its theoretical foundations are not widely accepted and no estimates on its current development and quantitative objectives are available.

Since 1992, and despite some improvements achieved within the Rio process, the global environmental problems have been worsening. The universal key finding of the United Nations Environmental Programme's (Clarke (ed.) 2000) Global Environment Outlook 2000 (GEO-2000) report is that continued poverty of the majority of the planet's inhabitants and excessive consumption by the minority are the two major causes of environmental degradation. The report's main assessment of the state of the global environment is that despite successes on various fronts, time for a rational, well-planned transition to a sustainable system is running out fast and in some areas has already run out. At the same time, new environmental problems are emerging which compound on already difficult situations. The report concludes that the present course is unsustainable and postponement of environmental protection actions is no longer a political option. (See e.g. Clarke (ed.) 1999, 4, 362, 364) The Living Planet Report 2000 (WWF et al. 2000, 1) quantifies these developments by estimating that the state of the Earth's natural ecosystems has declined by about 33 per cent over the last 30 years and, at the same time, the ecological pressure of humanity has increased by 50 per cent. Furthermore, the report argues that the ecological footprint of the global population is at least 30 per cent larger than the Earth's biological productive capacity.

Today, awareness of the global environmental problems threatening the integrity of world ecosystems has grown widely and the most commonly used environmental policy tools to deal with these problems have been international political agreements. The economic implications of the Rio process have been indirect and inadequate. On the face of it, there has been a widely accepted consensus among political decision-makers and leading economists that the functioning of the economy may not be disturbed by the demands of sustainable development. Thus, even the neoclassical solutions to the external environmental effects have not been applied and implemented. Several attempts to construct appropriate tools have been made among ecological economists, some of which have been successful and some have not. However, a convincing new economic perspective can be summarised and formulated from successful scientific efforts. Recent main lessons of ecological economics show convincingly that a transition to sustainable society can be achieved without endangering the basis of our welfare. In fact, a transition towards dematerialised production techniques and more eco-efficient society could even foster economic development and increase the level of welfare. In the near future, the obvious benefits of this desired outcome will probably overcome the reluctance of representatives of the old industrial society to accept societal changes.

2.2 An outline of the principles of industrial sustainability

The central problem to which the principles of sustainable development and the thinking of ecological economics are seeking answers is that the world economy has grown bigger in scale but the global ecosystem has not. The current growth of world population and per capita resource consumption alone lead to constant growth in the amount of environmental resources used and environmental hazards caused. Thus, this development generates economic growth that narrows the living space of nature. The 1972 Limits to Growth report to the Club of Rome (Meadows 1972), the concluding report of the Bruntland Commission in 1987 (WCED 1987), and the 1992 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.

Atkinson et al. (1999, 1) see that sustainable development aims for economic development in the traditional sense of rising wellbeing per capita, coupled with reduction in poverty and inequity, together with the requirement that the “resource base” of national economies and the global economy should not be depleted. In other words, Atkinson et al. (1999) define that the increase in the average human wellbeing must not be attained at the expense of worsening the distribution of present wellbeing, or at the expense of the wellbeing of generations yet to come. Thus, the thinking of the school of ecological economics concentrates very much on questions about the utilisation of natural capital. In the sphere of mainstream economics, this idea of sustainable economic growth is not a totally new one. The critical issue that is still unanswered is that there is no quantitative objective based on widely accepted scientific research results as to how much any given operation should actually be reduced. This fact must be borne in mind as background to the following analysis.

Common ground for all economists can be found from the fact that some reduction in the use of natural resources in production that is beneficial to the environment can also be beneficial to the economic activities in society. However, in practice the mainstream economic thinking has largely fallen back on old mercantile economic doctrines, especially with regard to natural resources and fossil fuels. Consequently, the majority of leading economists have been unwilling to recommend practical applications of the new approaches developed in the 20th century, such as the methods proposed by Arthur Pigou (1920) and Ronald Coase (1960) for tackling the underpricing of natural resources. 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 the supplies of these resources. Therefore, it can be argued that the prevailing economic policy has been causing environmental problems instead of solving them. Sustainable development can, therefore, be regarded from the economics point of view as a macroeconomic answer to the problems originating from an improperly functioning market price mechanism.

However, the application of the concept of sustainable development to the economic imperatives still remains an arena of struggle. In ecological economics, the interpretation of sustainable development has also diverged into two paradigms during the 1990s, namely weak and strong sustainability, which are defined with respect to various capital stocks. (Hediger 2000, 483) Neumayer (1999, 22–23) states that the reasons for this struggle over the correct interpretation of the concept of sustainable development in practice originate from the question of the substitutability of natural capital. The concept of weak sustainable development (WSD) is based on the work of the Nobel Prize winner Robert Solow and economist John Hartwick and it requires keeping the total net investment, suitably defined to encompass all relevant forms of capital, man-made, human or natural, above or equal to zero. Furthermore, weak sustainability allows the substitution of natural capital by man-made assets, provided it guarantees the current level of welfare also in the future. The weak interpretation of sustainability has also gained recognition among mainstream economists, although the majority of them do not consider sustainable development as a vital field of research at all.

In contrast to weak sustainability, the very essence of strong sustainable development (SSD) is that it regards natural capital as fundamentally non-substitutable with other forms of capital. Thus, strong sustainability means ecologically sustainable development that guarantees the future wellbeing of the present ecosystems. The advocators of strong sustainability include many ecological economists, such as David Pearce et al., Paul Ekins, Michael Jacobs, Clive Splash, Herman Daly and Robert Costanza. For evaluation purposes, this division into weak and strong sustainability is crucial. In 1991 the economist Herman Daly (at that time the Chief Economist of the World Bank) adapted the doctrines of the WCED into practical economic rules for ecologically sustainable development, which can today be defined as the basic rules of strong sustainability (SSD). According to Daly, the materials cycle between the natural environment and society should satisfy three conditions in order to be ecologically sustainable (Daly 1991; Meadows et al 1992, 170):

(1) The rate of use of renewable natural resources must not exceed the pace at which such resources are generated in the natural environment,

(2) The rate of use of non-renewable natural resources must not exceed the rate at which renewable substitutes for them are developed, and

(3) The rate of increase of polluting discharges must not exceed the capacity of the environment to absorb pollution.

According to these rules any sustainable economy should be based on the exploitation of renewable natural resources in a manner which does not jeopardise the scope and viability of the local ecosystem. In other words, these rules emphasise the imperative to keep the natural capital intact by keeping its utilisation at a sustainable level. They say nothing about the possibility of substitution so vital to weak sustainability thinking. These rules are, therefore, recognised by the ecological economics school of thought as the main organising principles of sustainable development. As an implication of these rules, technological development would have to be considerably accelerated and the current level of polluting discharges sharply reduced. Daly's rules thus pose a substantial challenge to the current economic systems.

These angles of strong sustainability have been combined by Nicolaisen et al. (1991, 14–15) into a formal presentation about income and consumption. The general argument is that if the current economic growth leads to a decline in future welfare measured as the per capita consumption potential of both marketable and environmental goods, the growth path would not be considered sustainable. Hence, in per capita terms, sustainability can be broadly defined as non-declining consumption potential. Consumption potential is in turn linked to future production potential and hence to capital stocks, measured in efficiency terms so as to include the effects of technological progress. If environmental resources are considered as a part of the capital stock, then the total of man-made and environmental capital cannot decline if total consumption of marketed and environmental goods is to be sustained. Thus, in per capita terms sustainable growth requires either non-declining stocks of both kinds of capital or sufficient substitution of productive capital for environmental capital to keep total stocks intact. (Nicolaisen et al. 1991, 14) According to Nicolaisen et al. (1991, 14–15) the consumption – or welfare – potential can in any time period be expressed as an increasing function of the amounts of the two types of capital:

(2.2.1) $$W = f(K, E),$$

where in each period of time and in per capita terms W equals consumption potential (welfare), K the stock of human-made capital, and E the stock of environmental capital. Introduction of the "sustainability constraint" that W is not allowed to decline in any period yields a necessary and sufficient condition for sustainable development:

(2.2.2) $$\Delta K \geq -q \Delta E \quad \text{or} \quad \Delta K + q \Delta E \geq 0,$$

where ΔE and ΔK are changes in E and K over time and q is the real shadow price of environmental capital measured in terms of human-made capital, i.e.:

(2.2.3) $$q = \frac{(W'_E)}{(W'_K)}$$

Hence, q is the shadow price (or cost) attached to an incremental change in environmental capital, measured in terms of human-made capital. According to (2.2.2), sustainability requires that the real value of environmental depletion must not exceed the real value of net investment in man-made capital.

In the presence of externalities, the market cost of pollution (i.e. the price paid on the market for the use of environmental resources) will fall short of the real shadow cost as expressed by q, the difference being the external costs imposed by polluters. External costs, which imply over-use of environmental resources, pose the inherent risk that the economy could follow an unsustainable path. Moreover, two factors strengthen the probability of such an outcome. First, as E falls, the marginal shadow price (q) of the remaining stock will rise; hence, given unchanged market costs of pollution, so will the external costs. Second, even if the stock of environmental capital is stabilised, its shadow price in terms of efficiency-augmented human-made capital will rise with income. Hence, for constant market costs of pollution, the total value of environmental degradation ($-qE$) will keep rising with growth in output and human-made capital stocks. In order to prevent this loss of welfare, the market costs of pollution may eventually have to increase. To ensure sustainability, the value of both types of capital should thus reflect their relative scarcity in the long run – as expressed by the shadow price.

Nicolaisen et al. (1991, 15) argue that there are strong reasons to believe that sustainable growth, as defined above, cannot be achieved in the long run unless the real market costs of pollution are rising towards the real shadow cost of environmental degradation. In addition, the development and adaptation of technologies to include sustainable growth may themselves be largely determined by the correct pricing of environmental resources. Moreover, as the environment is probably not an inferior good, the real shadow price of environmental services will continue to rise over time with economic growth and hence the market costs of pollution should rise accordingly. The sustainability issue is, therefore, intrinsically linked to the treatment of externalities. (Nicolaisen et. al. 1991, 15–16)

2.3 The society as a throughput economy

Section 2.2 presented the challenges of sustainability to economics as understood by economists. The same difficulties apply to the corresponding indicators developed to monitor the achievement of sustainable development. While the macroeconomists try to expand GDP by pricing environmental amenities and costs, the school of ecological economists takes a more interdisciplinary view. (Henderson 1993, 15) In this Section I aim to fit the approaches presented in Section 2.2. within the framework of ecological economics and take the analysis even further to the eco-efficiency thinking and its practical measures, as well as its environmental implications. As the starting point to this deepening of ecological economics to eco-efficiency analysis, I take the demand for strong sustainability (SSD), considered as the guiding principle of ecological economics. For example, the classification of indicators by Hanley (1999, 57) divides the indicators of sustainable development into three categories. As a measure of strong sustainability Hanley (1999, 57) refers to such measures as ecological footprints, eco-efficiency and Net Primary Production (NPP). Other strong measures include tools like Material Flow Accounting or Analysis (MFA), Design for Environment (DfE), Pollution Prevention or Cleaner Production, Life Cycle Assessment (LCA) and Extended Producer Responsibility (EPR).

These measures are based on a variety of ideas coming under the general title of industrial metabolism or industrial ecology, which view current societies as throughput economies and which as such carry out the rules imposed by Daly and presented in the previous Section 2.2. The roots of the branch of science known today as industrial metabolism lie, according to Fischer-Kowalski (1998, 70), in the late 1960s when it became culturally possible to take a critical stand on economic growth and consider its environmental side effects. Earlier, the mainstream of social sciences, whether economics, sociology or political sciences, had not been concerned with this issue at all. In the mid-1960s things started to change, apparently originating from the United States. Fischer-Kowalski (1997, 21) regards Wohman, Boulding, Ayres and Kneese as the early pioneers of industrial metabolism and material flow accounting and analysis. Wohman (1965) was the first to attempt to conceptualise and operationalise the metabolism of an industrial society by presenting the first empirical estimate of the metabolism of a model U.S. city. In his article Wohlman (1965, 179) stated that *"the metabolic requirements of a city can be defined as the materials and commodities needed to sustain the city's inhabitants at home, at work and at play… The metabolic cycle is not completed until the wastes and residues of daily life have been removed and disposed of with a minimum of nuisance and hazard."*

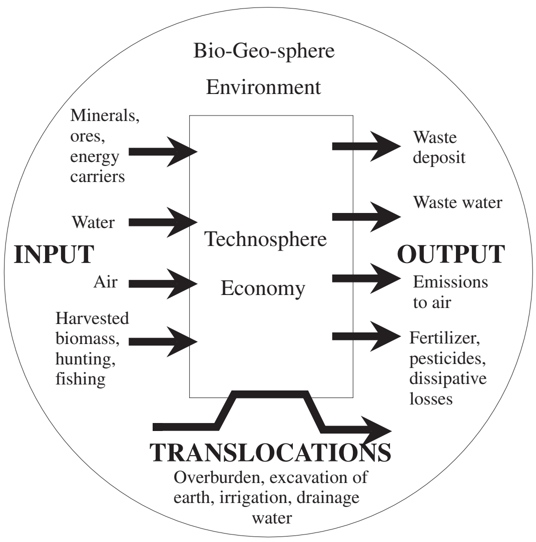
Scarcity of the natural world and of economies was made the central issue in economics by another early pioneer, Kenneth Boulding (1966), who described the existing economic system of the industrialised countries as an old "cowboy economy" and imposed as an objective the idea of a new "spaceship economy" with material cycles in a closed system. It was

Boulding's view that the target of the economics of this new system would have to be that of minimising the use of raw materials. Boulding's ideas inspired several attempts to model this closed material cycle between the natural and economic domains. The first comprehensive empirical material flow analysis for the USA was presented by Robert Ayres and Allen Kneese (1969) and they also related it to the population and GDP. The original introduction in material balance models, derived from the laws of thermodynamics, was based on an article published by Ayres and Kneese in 1969, in which they stressed that pollution was an unavoidable and permanent phenomenon caused by production and consumption. According to Ayres and Kneese, the ability of the natural environment to transform waste and pollutants back into forms which are of value to human beings (i.e. into natural resources) is limited and requires extremely long periods of time by human standards. Since, the cycle of materials based on the laws of thermodynamics on the earth is a largely closed one, rapid growth in production and consumption (not counting qualitative growth) leads to a situation in which the natural environment is no longer able to "clean up" the by-products of economies. For example, Fischer-Kowalski (1998, 72) recognises the contribution of Ayres and Kneese (1969) as a starting point to a research tradition capable of portraying the material and energetic metabolism of advanced industrial economies.

The idea of a closed circle of materials and energy on the earth was applied in the Club of Rome's 1972 Limits of Growth report in which the only means of avoiding a catastrophe in the wake of exhaustion of natural resources was felt to be that of stopping the prevailing economic growth. This report stated quite straightforwardly that as production volumes grew it would be necessary to use increasing amounts of energy and raw materials, but that there is only a limited quantity of these available on the earth. Furthermore, due to underpricing of natural resources the production system in industrialised societies could continue to be economically efficient even though in practice it squanders raw materials and energy. As a solution to the imminent problem of exhaustion of natural resources, the report proposed calling a halt to increasing consumption of materials and energy. Economic growth should, instead, be sought in improved production methods, i.e. in what is known as qualitative growth. At the same time (1971, 1973) the American economist Herman Daly proposed a transition of economies to a stationary state (known as Steady-State Economy) in order for the global economy to remain within the boundaries imposed by the laws of ecology and thermodynamics. In practice, however, the succeeding oil crisis, economic recession, unwillingness of societies and industries to undergo structural reforms and new discoveries of natural resource deposits distracted attention away from the finite character of the natural environment and towards cleaning up and reducing the undesirable side-effects of production processes in the late 1970s and in the 1980s.

Consumption of natural resources in general, and the environmental problems that followed growth became a topic of interest once more in the mid-1990s. According to Gardner and Sampat (1999, 50) already in the early 1990s the environmental problems associated with intensive materials use led to calls for a "dematerialisation" of industrial economies: a reduction in the use of materials needed to supply the services people want. By the mid-1990s the transformation of raw materials into commodities, discharges and waste were being described in ecological environmental economics with the expression industrial ecology, i.e. employing a concept originally derived from biology. This point of view utilised Kenneth Boulding's still valid basic idea of transforming the primary materials derived from the natural environment through processes of technosphere into waste for ultimate disposal. Material throughput is characteristic of the current production structures of the industrialised countries, and various researchers, including Herman Daly (1992), Robert Ayres and Udo Simonis (1994), have actually used the expression "throughput economy" for the current economic system. The idea of a "throughput economy" according to Bringezu (1997) is shown in Figure 1.

Figure 1.
The "throughput economy" system based on material flows caused by mankind



In the 1990s, ecological economists reaching for new environmental macroeconomics and trying to overcome the narrow view of neoclassical economics have devoted themselves to the volumes of the exchanges that cross the boundary between systems and subsystems. Daly (1991, 37) distinguishes two dimensions in the conventional term of economic growth. First, the concept of economic development, which means getting more service per unit of throughput and, second, the concept of economic growth, which refers to increasing service by increasing the size of stocks. 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 and then arriving finally back at the natural environment. Daly advocates strongly the stimulation of economic development by holding the environmental resource stocks constant. According to Daly (1991), 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 create the service direct, but must first be changed into human-made capital stock. All services, however, are originally derived from natural capital stocks and so, in fact, it is precisely these that satisfy our needs. The human-made capital stocks are merely interim stores comprising organised structures that have been frozen for a while. On the 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 (2.3.1):

$$(2.3.1) \quad \underset{(1)}{\frac{\text{Service}}{\text{Throughput}}} = \underset{(2)}{\frac{\text{Service}}{\text{Stock}}} \times \underset{(3)}{\frac{\text{Stock}}{\text{Throughput}}}$$

Ratio (1) of formula (2.3.1) 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, and ratio (3) the stock-maintenance efficiency of the throughput. The concept of economic development consists of 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 of stocks, but with no increase (and possibly a decrease) in the efficiency ratios (2) and (3). (Daly 1991, 37)

Daly (1996, 48) identifies as the subject matter of emerging environmental macro-economics the physical exchanges crossing the boundary between the total ecological system and the economic subsystem. These resource flows are considered in terms of their scale or total volume relative to the ecosystem and its safe carrying capacity. Daly uses the term “scale” as a shorthand for the physical scale or *size of the human presence in the ecosystem as measured by population times per capita resource use.* The safe ecosystem carrying capacity boundary thus marks the optimal scale of the whole economy. This boundary cannot be crossed without disturbances to the environment. Thus, the major task of environmental macroeconomics is to define the optimal absolute scale or size of economy. Daly also distinguishes two concepts of optimal scale. The first is the anthropocentric optimum, which means expanding the scale to the point at which the marginal benefit of additional man-made physical capital to human beings is just equal to the marginal cost to human beings of sacrificed natural capital. The second one is the biocentric optimum at which other species and their habitats are preserved beyond the point necessary to avoid ecological collapse or cumulative decline. Daly states that the definition of sustainable development does not specify which concept of optimum scale should be used. (Daly 1996, 48, 50–52)

2.4 Dematerialisation and Factor -targets

The current phase of evolution in ecological economics includes Industrial Ecology (Graedel & Allenby 1995) and Industrial Metabolism. According to Anderberg (1998, 312) the concept of Industrial Metabolism was first introduced by Robert Ayres in 1988. The aim of industrial metabolism studies is to gain improved knowledge and understanding of societal uses of natural resources and their total impact on the environment. The basic idea is to analyse the entire flow of materials and identify and assess all possible emission sources and other effects in connection with these flows. Since the 1970s, an important thread within these industrial material cycle themes has been the so called dematerialisation of economies. Cleveland and Ruth (1999, 16) argue that dematerialisation refers to the absolute or relative reduction in the quantity of materials used and/or the quantity of waste generated in the production of a unit of economic output. For example, several empirical studies conducted suggest that the economies of the OECD counties have dematerialised or even decoupled (e.g. see Hammond – Matthews 2000, 85). Several researchers attribute this to a “natural” or “evolutionary” process driven by the maturation of economies or rising incomes. Some researchers even suggest that this apparent dematerialisation leads to a situation where human economy can decouple itself from energy and material inputs by a factor of ten. (Cleveland & Ruth 1999, 16)

The hypothesis underlying the environmental Kuznets curve (EKC), a widely used indicator of sustainable development, is that resource depletion and pollution increase in the initial stages of development but tend to fall as incomes rise, producing an inverted U-shaped function. According to Cleveland and Ruth (1999, 25) most empirical analyses find support for the EKC hypothesis. Some of the most optimistic studies assume that rising incomes will substantially decouple materials use and economic growth. The standard explanation is based on the following assumptions: in the early days of development, incomes and also material requirements are low but industrialisation drives an increase in the materials demand of building basic infrastructures. As development continues, the need for basic infrastructures declines and consumer demand shifts increasingly toward services, which are assumed to be less materials intensive. (Cleveland & Ruth 1999, 25)

According to Reijnders (1998, 14), one of the emergent ideas in the 1990s pertinent to reducing the environmental impact of economic activities is the factor X reduction in resource use, with X being between 4 and 50. The lower values – a multiple of four – relate to short-term possibilities for environmental improvement while the higher values indicate longer-term improvement potential. As a concept, factor X is located somewhere in the grey area between science and policy, since there is no agreement on the environmental impact factor X refers to. Thus, factor X is qualitatively similar to the concepts of "dematerialisation", "eco-efficiency", and "increased natural resource productivity" since it relates to the debate on the relative contributions of population, affluence and technology to the environmental impact of economies. Factor X debate concentrates largely on the technology factor of such a formula. According to Reijnders (1998, 18), several studies have shown that major changes in the pricing system for changing affluence are a necessity for the achievement of factor X. Furthermore, implementation of the factor X targets suggests environmental improvement, or "ecological modernisation". However, it seems reasonable to expect that many factor X technologies will, with the current pricing system that largely externalises environmental costs, be costlier than the current ones. (Reijnders 1998, 18).

In 1994, the need to quantify the reductions needed in materials consumption lead von Weiszäcker, Lovins and Lovins (see Weiszäcker et al. 1997, xviii) to popularise the above mentioned empirical findings to the so called Factor 4 target, which is an objective whereby the input of natural resources, raw materials and energy in each unit of production is to be reduced to one quarter of its current level in the medium term, i.e. over the next 20 to 30 years. In addition, the Factor 10 target was developed, that is an objective whereby the input of natural resources, raw materials and energy in each unit of production is to be reduced to one tenth of its current level in the long term, i.e. over the next 30 to 50 years. The objective is analogous with the calculated need to reduce global carbon dioxide emissions by 90 per cent in order to prevent the greenhouse gas phenomenon. The Factor targets are introduced against the global warming, or greenhouse, phenomenon since most of the environmental problems arise from the use of fossil fuels. Today, the environmental damage caused by the growing use of fossil fuels is considerable and is in many places threatening the life-supporting systems of the biosphere. As well as to carbon dioxide emissions, the Factor targets can also be applied to society's materials use, which is the ultimate source of environmental degradation.

The Factor 10 objective to improve the current natural resource productivity has been advocated by the Factor 10 Club, established in 1994 to promote dialogue about reducing material flows per unit of service. According to the Carnoules Declaration this ten-fold increase in energy and resource productivity also requires other factors besides technological development. (see Schmidt-Bleek 1995, 8, 24) According to Hinterberger et al. (1997, 8) studies at the Wuppertal Institute and elsewhere have shown that increasing resource productivity by factor four or five is within reach now. In addition to the Factor 4 and 10 targets, other objectives have also been suggested. A Factor 20 or more for environmental improvement over a 50-year period was the focus of the Dutch research programme Sustainable Technological Development (1992–1997) that concentrated on technical change. In other studies, values of X up to 50 for the economy as a whole have been proposed for achieving a steady state economy or sustainability. (Reijnders 1998, 14) In the following Chapter 3 I discuss the eco-efficiency approach, aiming to track these factor targets, in more detail.

3 The basis of the eco-efficiency analysis

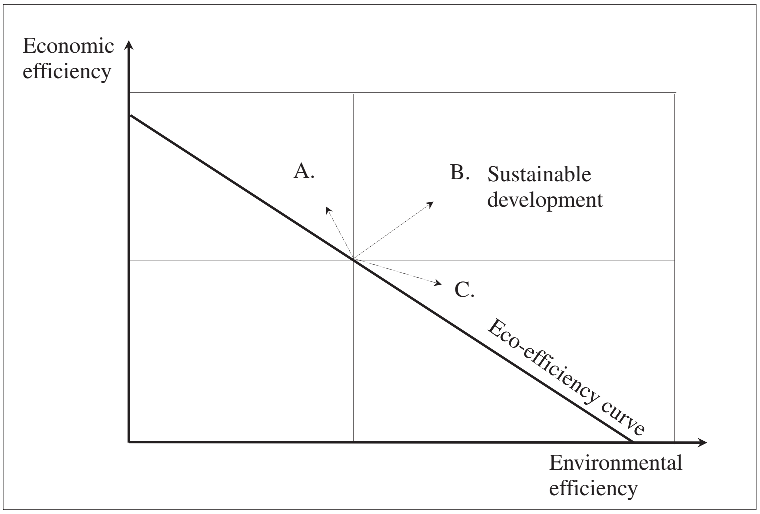
3.1 Formation of the eco-efficiency approach

The concept of *eco-efficiency* was introduced 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 economics, especially from 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 the 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 (1992) defined ecological efficiency as the desired output per environmental impact added. 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 impact covers all effects on the environment according to their relative degree of environmental impact (Helminen 1998, 39).

Schaltegger and Burritt (2000, 53; Schaltegger et al. 1996, 126) describe the relationship between sustainable development and eco-efficiency using Figure 2.

Figure 2.
Eco-efficiency of sustainable development as an operating strategy



Source: Schaltegger & Burritt 2000, 53; Helminen 1998, 40.

In Figure 2 arrows A, B and C describe the paths of development leading to improved eco-efficiency that 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, although there is only movement in the direction of sustainable development if both economic and ecological efficiencies improve (arrow B). When such a direction of the change occurs, 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 the change is only towards economic efficiency (towards area A) there is a loss of environmental efficiency and when the change shifts too far towards environmental efficiency (towards area C) there is a loss of economic efficiency. In spite of its utility, Figure 2 is unable to allow for the third dimension of sustainable development, i.e. social justice, equality and ethics, and this is its greatest weakness (Helminen 1998, 39).

The concept of eco-efficiency has a very close resemblance to the above mentioned ideas of Herman Daly concerning the measurement of the sustainability of throughput. However, the major difference from the formula (2.2.3) of Daly is the inclusion of the total stocks of natural capital. Since measurement of the stocks of natural capital is difficult and, at best, also very inaccurate, I will from now on rely on the eco-efficiency approach that excludes the stocks from the throughput analysis.

3.2 Combining economic efficiency with environmental efficiency

The concept of eco-efficiency, i.e. the combining of efficient use of materials in production and economic affluence, was first proposed for environmental policy use by the Business Council for Sustainable Development (BCSD) in its report to the 1992 environmental conference in Rio de Janeiro. The BCSD itself was originally formed to offer a "business perspective" to the UNCED Conference in Rio de Janeiro in 1992. (Helminen 1998, 9) It later merged with the World Industry Council for the Environment (WICE) to form the WBCSD in 1995. The BCSD viewed eco-efficiency as a means of reducing consumption of natural resources and pollution while improving competitiveness in the enterprise sector. At the practical level eco-efficiency means that consumption of materials (natural resources) must be reduced in order to reduce undesirable environmental impacts. At the same time, smaller amounts of materials should produce more evenly distributed economic affluence. Thus the general and practical objective of the eco-efficiency approach is "to get more out of less" (otherwise known as achieving qualitative growth). It is possible to measure not only the eco-efficiency of an individual enterprise or product but also that of an entire economy. Gardner and Sampat (1999, 51) see the modest decrease in materials intensity since 1970 as largely due to an unplanned spin-off of other economic and social developments. As roads, houses, bridges and other major works of infrastructure were largely completed in the industrialised countries, lighter materials were utilised and recycling programmes started, and services that were less materials-intensive grabbed a larger share of the economy.

Inspired by the example of the WBCSD, European enterprises have since the mid-1990s become interested in applying the viewpoint of eco-efficiency to their environmental management and reporting. From the perspective of an enterprise, the idea of eco-efficiency means taking practical measures to reduce the amount of energy invested in products over their life cycle, reducing the use of toxic substances, improving the recyclability of materials, maximising sustainable use of renewable natural resources, improving the durability of products and improving their suitability for their intended purpose. Applying the concept of eco-efficiency means that value added can ultimately accrue both to the enterprise and to society as a whole, which will increase the shareholder value currently regarded as particularly important.

The driving force for the European companies to apply the principles of eco-efficiency to their activities is the consumers' growing concern over the environment. For example, in their report to the WBCSD, Blumberg, Korsvold and Blum (1996, 12–13) see that environmental concerns will continue to grow and the companies which still ignore them will risk losing their licences to operate or markets to serve. Because the environmental drivers are here to stay, ignoring them is to miss an important element of competitive advantage. Although the techniques used by companies vary from company to company, some general principles may be formulated, which, if followed, can yield concrete performance improvement and competitive advantages. These include:

1. Integrating environmental drivers into their overall business strategy,
2. Paying close attention to how consumers value environmental product qualities,
3. Subjecting environmental investment proposals to the same appraisal process as any other investment proposals,
4. Increasing energy efficiency per unit produced,
5. Reducing negative impacts (emissions, discharges, wastes) on eco-systems,
6. Recycling or using “waste” material,
7. Reducing the cost of credit since environmental risks are well taken into account,
8. Increasing raw materials efficiency per unit produced, and
9. Extending service and enhanced functionality.

At the moment the WBCSD is co-organising the European Eco-efficiency Initiative (EEEI), a two-year awareness raising and competence building exercise, to promote eco-efficiency as a leading business concept across Europe, both for industry and governments. The project is a model for a multi-stakeholder project involving industry, governments and other stakeholders in fostering joint progress. The EEEI intends to spread the messages and achievements of eco-efficiency to a broader business community, integrate the concept into policy programmes and formulate a multi-stakeholder agenda, comprising activities at the European level, as well as at the national level, in all EU Member States. The idea is to examine the role of eco-efficiency in the fostering of European competitiveness and present the ideas to the United Nations Earth Summit III in 2002. The European Union also has its own Eco-efficiency Initiative (European Union 1998).

Besides the WBCSD, the OECD, the European Union and the U.S. President’s Council for Sustainable Development (PCSD) have also shown increasing interest toward eco-efficiency thinking. The eco-efficiency proposal prepared by the European Union in April 1997 regards technological and policy development, together with changes to 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 the patterns of production and consumption so that eco-efficiency could be promoted at national levels (European Union 1998). At the proposal of 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 the patterns of production and consumption in the concluding document of the UNGASS Conference held in New York in June 1997.

The Organisation for Economic Co-operation 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 contents of the notions associated with sustainable production and consumption, including eco-efficiency, took place in 1995 at a working conference arranged in Norway. According to Michaels (1998, 54), in their meeting in February 1996, the OECD environment ministers asked the organisation to examine the potential of "eco-efficiency" as a strategy for decoupling economic growth from resource use and pollutant release. Then, in their meeting in March 1998, the ministers asked the OECD to work on policies for the improvement of resource efficiency.

The background report (OECD, 1998) compiled for the 1998 conference of the OECD environment ministers showed that the intensity of energy, materials and land use in relation to GDP was falling at an annual rate of two per cent in the OECD Member States. However, such reductions in natural resources use and pollution volumes are insufficient to achieving the Factor 10 efficiency target within the next 30 years. It is estimated that the improvement in materials efficiency over the next 30 years will correspond to the Factor 2 targets. 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 ten per cent improvement over longer periods and 35 per cent improvement over shorter periods, have been achieved under certain circumstances. High degrees of eco-efficiency are typical of the high technology sectors in which it has been possible to apply significant scientific inventions to products within very short time periods. (Michaelis 1997, 17)

Michaelis (1998, 58) states that the priority in the OECD's future work is to identify and evaluate policy experiments targeted towards improving resource efficiency. A series of empirical case studies is also to be carried out in the OECD Member States. These will include evaluation of the effectiveness of specific initiatives to improve resource efficiency taken by firms and local and national governments, and that of large-scale and long-term processes influencing resource efficiency at the sector level, and the economy as a whole. Case studies aim to bring expertise to bear on them from a range of different disciplines. Michaelis (1998, 58) concludes that it remains to be seen whether a single, coherent conceptual framework will emerge or whether we need to continue to emphasise the role of multiple viewpoints.

The President's Council on Sustainable Development (PCSD) was appointed in the U.S.A. in June 1993 to advise the U.S. President on 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 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 the policies of 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 (PCSD 1996).

In its recent report, the President's Council on Sustainable Development (PCSD 1999, 46), recommends that environmental progress should be measured so that we can be confident that progress is being made to achieve the national and local environmental goals. The Council also recommends linking environmental performance information with economic and social information. They see that the paramount goal in integrating diverse types and levels of information is to affect the decision-making process so that sustainable development opportunities become more obvious and, therefore, logical and desirable. The PCSD (1999, 109) sees that the value of environmental performance information is under threat of being diminished by the proliferation of differing approaches. It is often difficult to develop sufficiently comparable information on environmental performance across a single company, let alone a whole sector or a nation. The problems are further compounded by differing definitions from one country to another. Locally developed metrics can also be too insular, or they may not reflect the accepted national standards or goals. Thus the PCSD argues that one of the most important challenges ahead is to devise metrics that serve the specific needs of users while simultaneously contributing to greater comparability across firms, communities, industries, states and nations. The necessary architecture of such an information system depends on the specific type of information under consideration:

1. Environmental performance metrics/indicators that measure potential human stresses on the environment (e.g., pollutant releases, transportation, natural resource depletion, etc.)

2. Environmental management indicators that measure efforts for reducing or mitigating environmental effects (e.g., regulatory programmes, corporate environmental performance, and community, state, or national levels of performance)

3. Environmental condition indicators that measure environmental quality (e.g., ambient air or water quality); and

4. National accounts information that tracks natural resources and natural assets at the state and national levels (e.g., the green gross domestic product) and internally, managerial practises that track environmental management performance and values within facilities, organisations and firms.

In practice, eco-efficiency is measured in various ways at the company level. However, the implementation of the strategy and its accounting methods at the national economy level has not been done before. To do this, I take a closer look at the measuring tools of several companies in the next Section 3.3.

3.3 Measuring eco-efficiency in companies

Many companies have received the WBCSD's sustainable development challenge formulated into the eco-efficiency principles. For example, Blumberg et al. (1996) mention that the principles of eco-efficiency are taken into account in the activities of British Gas (UK), Bröderne Hartmann (Denmark), Ciba (Switzerland) Danish Steel Works (Denmark), Dow Chemical (USA), DuPont (USA), F. Hoffman-La Roche (Germany), Kvärner (Norway), Neste (Finland), Novo Nordisk (Denmark), PowerGen (UK), Sony (Japan), Stoebrand (Norway) and Swiss Bank Corporation (Switzerland). All these companies have done significant work in order to meet the eco-efficiency principles. However, one common problem remains that hampers the development. This problem is lack of information about the companies' eco-efficiency performance.

Until now, the urgency to solve environmental hazards in societies has often met up with lack of accurate information. Kuik and Verbruggen (1991, 1) state that unless there is some clear measure or at least some indicator of sustainable development, the effectiveness of environmental and related policies toward this goal cannot be assessed. One can summarise this phenomenon as "no data, no policy". In the business world the same phenomenon is formulated into "you can't manage what you can't measure". Thus, measuring eco-efficiency enables the necessary targeting of actions to achieve sustainable development. However, measuring eco-efficiency is no easy task in practice. According to the theory, true eco-efficiency measures should show how more output is being obtained from a given resource input or environmental effect. While expressing the input in physical units, say in tonnes, and the resulting output in economic terms, say company turnover, for example, there is a danger that the measures improve not because of real environmental actions but because of other changes such as inflation of revenues through price increases, corporate reorganisations or acquisitions. Another problem is that although an individual organisation can claim that its activities and products are becoming more eco-efficient, this may not say anything about their sustainability.

Four types of approach to the measuring of eco-efficiency can be found in the business world. The first solution to the measuring problem relates to the eco-efficiency of company operations. According to DeSimone and Popoff (1997, 80), for example, Novo Nordisk Company track their resource productivity through Eco-Productivity Indices (EPI). These relate the corporate turnover, adjusted for exchange rate and price fluctuations, to the corporate consumption of the key inputs of raw materials, water, energy, and packing. Their formula (3.3.1) is:

$$(3.3.1) \qquad EPI = \frac{\text{indexed turnover at constant prices}}{\text{indexed resource consumption}} \times 100$$

The higher the value of the EPI is, the more eco-efficient the company has been in utilising the resource. When making the calculations, the annual turnover figure is adjusted for exchange rate and price fluctuations and indexed to the level of 1990, which is set at 100. The resource consumption is expressed in physical units and also indexed to the 1990 level. The Swiss pharmaceuticals enterprise Roche has developed the Eco-Efficiency Rate (EER) indicator, which is calculated by dividing the value of the sales of the enterprise's production by its 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. (DeSimone & Popoff 1997, 80)

The eco-efficiency of products has also been measured by companies with various methods. The first example of this is Sony Europe's measure of eco-efficiency, which is called the Resource Productivity Index (RPI). The RPI relates an economic variable, e.g. value added over a product's lifetime, to an environmental one, e.g. a composite of energy and material intensity and recycling. As a formula, Resource Productivity Index (RPI) can be expressed as the following equation (3.3.2):

(3.3.2)

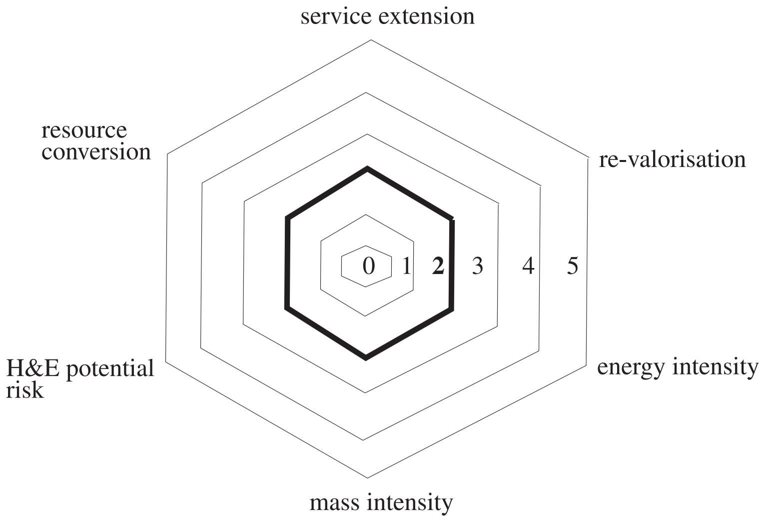
$$RPI = \frac{\text{economic value added} \times \text{product lifetime}}{(\text{material consumed} - \text{recycled}) + \text{energy consumed} + \text{lifetime energy used}} \times 100$$

Formula (3.3.2) enables comparisons between different options. For example, Sony has used it to compare the resource productivity of three different batteries – non-rechargeable manganese-zinc, rechargeable nickel-cadmium and lithium-ion. By this method, the lithium-ion batteries proved to be by far the most eco-efficient.

The second example of product eco-efficiency measurement is also based on the use of indicators. A number of companies, including Philips and Volvo, have developed in collaboration with government research institutes a set of eco-indicators which assign eco-points. Eco-points reflect the seriousness of environmental impact. Volvo has used its Eco-Points Scheme, or Environmental Priority Strategies (EPS) system, to assist design engineers in the selection of environmentally preferable materials for product construction.

The third example of product eco-efficiency measurement utilises indicators in an exceptional, new way. Dow Europe has developed an eco-compass to compare different products. The eco-compass gives to products scores in relation to six eco-efficiency dimensions, which broadly correspond with the seven topics listed by the WBCSD to clarify the eco-efficiency concept. The general idea of the eco-compass approach is presented in Figure 3 (Fussler & James 1996, 153):

Figure 3.
Dow's eco-compass



Source: DeSimome & Popoff 1997, 83.

A new or revised product is given a score for each dimension on a scale of 1 to 5. The scoring is relative to a base case, usually an existing product, which always scores 2. In the eco-compass scale, 0 represents the case in which the performance per functional unit decreases by 50 per cent or more, 1 where it decreases by up to 50 per cent, 2 represents no significant variation from the base case, 3 up to 100 per cent improvement per functional unit, 4 up to 300 per cent increase and 5 more than 300 per cent increase in performance per functional unit. To ensure fair comparisons, each score is based on the environmental impact of one standard unit of service. The scores of the base case and the alternative(s) can then be mapped on the compass (Figure 3) to provide a visual comparison of their eco-efficiency.

Each approach to the measuring of a company's eco-efficiency has several advantages and drawbacks. Novo Nordisk's corporate level approach is useful for showing broad trends and improvements in overall performance. However, operational management requires a more disaggregated approach giving site and raw material-specific data. Sony Europe's measure (RPI) is highly useful in product comparisons, but has the limitation of addressing only two of the eco-efficiency guidelines, i.e. energy and materials. The inclusion of turnover also means that higher prices would improve the score. Volvo's EPS – Eco-Point Scheme has the strength and weakness of a conversion of different environmental hazards into a common unit. This is due to the lack of consensus on how to weight the different impacts. Dow's eco-compass has the advantage of providing clear visual comparisons when considering how to improve a product's eco-efficiency. The main obstacle in the eco-compass is also the weighting of the different dimensions.

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 the wide variety of currently prevailing indicators. (Eco-efficiency Task Force 1998, 19–21; Michaelis 1997, 8–10)

Most of the desired improvements of eco-efficiency can be achieved through the implementation of already available technological innovations. For example, Weizsäcker et al. (1997) have identified some 50 examples of how to quadruple resource (energy, materials and transport) productivity in practice. Most of these examples also produced considerable cost savings for companies and thus improved their profitability. For instance, Procter & Gamble have estimated that their waste minimisation efforts have generated benefits of USD 25 million at one of its plants alone. If a company does not recognise and exploit the business opportunities that operating along the lines of eco-efficiency principles can offer it will eventually lose money. That is why correct information about the company's eco-efficiency is also becoming vitally important to the company's management.

According to Lehni (1999), the WBCSD has also recently developed a set of eco-efficiency indicators to help measure progress toward economic and environmental sustainability in business. These eco-efficiency indicators primarily serve as a decision-making tool for internal management to evaluate performance, set targets and initiate improvement measures. They are also an important tool in communicating with internal and external stakeholders. As the intention of eco-efficiency is to maximise value while minimising adverse environmental impacts, i.e. use of resources and impacts from emissions, the WBCSD has developed an equation for businesses for calculating eco-efficiency. This equation merges value and ecological aspects into an efficiency ratio (3.3.3):

$$\text{(3.3.3)} \quad \text{eco - efficiency} = \frac{\text{product or service value}}{\text{environmental influence}}$$

Equation (3.3.3) can be used to calculate several different eco-efficiency ratios. Specific calculations will depend upon the needs of individual business managers and on the values and impacts specific to their particular business sector. The equation strives to improve economic and environmental efficiency, but does not pertain to social issues. Yet, eco-efficiency as such is the key for diverting businesses and governments toward sustainable development. (Lehni 1999)

Apart from these company-designed eco-efficiency measures, the MIPS index (Material Input Per Service), developed in the mid-1990s by the German Friedrich Schmidt-Bleek and the Wuppertal Institute, can also be used to analyse the eco-efficiency of products and services. 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, both direct and indirect, brought about by a product or service over its entire lifespan. The material inputs that 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 the consumption of a litre of orange juice involves a hidden material flow 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 ecological footprint per capita describes the productive land area a single consumer needs to sustain his level of consumption. (Weizsäcker et al. 1997, 242–244)

3.4 Measuring the eco-efficiency of an economy

According to the OECD (1998, 69), eco-efficiency is open to a variety of interpretations. Eco-efficiency is necessary, but not sufficient, for sustainable development. The research area of eco-efficiency and its practical measurement is also very diversified by nature and the potentials for reducing societies' material consumption are not yet fully understood. For example, with the exception of a few countries, material flow management – beyond energy and waste management – is still not a really important target for the existing national sustainability strategies. The policy pull toward national MFA is still weak – sometimes in contrast to a regional one and always in contrast to the spread of eco-auditing within industry. However, the statistical paradigm oriented towards MFA can, indeed, influence the national policy debate.

Chambers et al. (2000, 15) state that it is necessary to also be able to measure the elements of sustainable development. Measuring any of the sustainability parameters – environmental, social and economic – in themselves is, however, not an easy task. Some critical data are not available or cannot be readily compared with other places or times and many essential qualities simply cannot be expressed in numbers. According to Chambers (2000, 15) the right decisions need credible, accessible and timely information. These qualities can be provided by the use of indicators.

Adriaanse et al. (1997) have done remarkable research over the 20-year period from 1975 to 1994 in seeking to provide a quantitative physical description for all the natural resources directly and indirectly used by the economic activity of certain industrial countries, even when portions of that use occur outside the country's borders. Their study also aims to add to the information and tools available for decision-making. Adriaanse et al. (1997, 8) call the total physical requirements of a national economy as the Total Material Requirement (TMR). Thus the TMR includes all domestic and imported primary natural resources, together with their associated hidden flows, and complements the monetary measures, like the GDP, of a nation's economic activity. The TMR can be considered as an approximate measure of the potential pressure exerted by an economy on the global environment, though precise measures will depend on the disaggregated components of the TMR, and on their environmental impacts. Physical and monetary measures combined provide a more complete view of the size and scope of an industrial economy. Adriaanse et al. (1997) also utilise an economy's use of natural resource commodities, or the Direct Material Input (DMI), which is the quantity of the TMR less the domestic and imported hidden flows.

On the input side of economy, agriculture, forestry, fisheries, mining and oil or gas wells extract or harvest primary materials. Industrial processes then transform these inputs to products and services. Adriaanse et al. (1997) exclude water and air from their study. All other natural resources removed from the environment to support economic activities are accounted for, as also are materials moved or processed. Extracting or harvesting primary natural resources often requires moving or processing large quantities of materials that can modify or damage the environment even though they have no economic value. These flows are classified as hidden flows (HF). Since there are no markets, or prices, for the hidden flows, economic accounts do not usually include them. As a result, the natural resource dependence of an industrial economy is underestimated and decision-makers are given a distorted picture of the physical scale and consequences of economic decisions. (Adriaanse et al. 1997, 5–7)

The eco-efficiency analysis of a national economy of Adriaanse et al (1997, 13–14) is very limited in scope as it mainly measures the overall materials intensity trend by the TMR/GDP ratio. In their opinion the TMR/GDP ratio provides the best measure of a country's material intensity or overall eco-efficiency, because it includes extractive activities and other hidden flows. At the same time, the DMI/GDP ratio signals the presence or absence of technology-related changes or industry-related practices that increase the efficiency of materials use. According to Bringezu (1997, 47) Total Material Input (TMI) comprises the national and transnational (i.e. the global) material extraction from the environment. It can be regarded as a highly aggregated indicator that relates to the global environmental pressure associated with the physical basis of an economy. Bringezu sees (1997, 47) that the TMI may be used as a basis to indicate the overall material productivity of an economy. The relation of GDP to TMI provides the material productivity of GDP. This indicator can be interpreted as a measure of eco-efficiency. However, an increasing figure for this indicator does not necessarily reflect reduction in the absolute environmental pressure. For the purpose of international comparisons between Germany, USA, Japan and the Netherlands the TMI was re-named Total Material Requirement (TMR) in order to reflect the fact that the rucksack part of the extraction flows (in this case called hidden flows) are not direct inputs of the economies studied.

It should be borne in mind that Adriaanse et al. (1997, 6) also recognise in their study the fact that different materials have qualitatively different impacts on the environment. These aspects can be taken into account by segregating material flows by their long term impacts on the environment, ranking all flows as either major or minor by both the degree of mobilisation of the material and its potential for causing environmental harm. By applying this approach to the U.S. data, it has been estimated that the percentage of the total flow in each category gives the following results:

1.	High mobilisation, high potential for harm	12%
2.	High mobilisation, low potential for harm	29%
3.	Low mobilisation, high potential for harm	5%
4.	Low mobilisation, low potential for harm	54%

The first category is perhaps the most important from the long-term national sustainability perspective. The third category of flows may be of greatest concern locally. Thus, by disaggregating the aggregate material flows their qualitative characteristics can be measured.

In addition to the above described company and national economy levels, Helminen (1998) has also 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 value added to environmental impact) is greater than that of the reference plant (Helminen 1998, 82). The study evaluates eco-efficiency using various weighted environmental impact indices alone, without making any allowance for the 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 it.

One particular measure of strong sustainability, relating partly to the eco-efficiency approach, is the Ecological Footprint (EF), which was introduced by Rees (1992) and elaborated upon by Rees and Wackernagel many times since 1994. (Ayres 2000, 347) In addition to being a strong measure of sustainability, the EF can be regarded as a technologically "sceptical" indicator (while eco-efficiency is a more or less "optimistic" indicator) that tends to maintain the view that self-sufficiency is a necessary condition for sustainability. The Ecological Footprint (EF) for a particular population is defined as the total area of productive land and water ecosystems required to produce the resources that the population consumes and to assimilate the wastes that the population produces, wherever on earth that land and water may be located. The EF has been widely praised as an effective heuristic and pedagogic device for presenting current total human resource use in a way that communicates easily to almost everyone. According to Moffatt (2000, 360), the advantages of the ecological footprint (EF) concept are that it gives a clear, unambiguous message, often in an easily digested form, is simple to calculate, includes trade and is a stock measure. The limitations of the EF are that its ability to function as a sustainable development indicator remains doubtful, it provides a static analysis, ignores technological change, underground resources and material flows, lacks measures of equity and provides no policy prescriptions. Moffatt (2000, 361) concludes that as a method for raising awareness of our impact on the earth the EF is strikingly clear. Costanza (2000, 341) argues that the controversy of the EF approach emerges when one moves from simply stating the results from an EF calculation to interpreting them as indicators of something else. The EF has been proposed as an indicator of biophysical limits and sustainability, i.e. if one's EF is bigger than the land area under one's direct control then overshoot has occurred and one has exceeded one's sustainable resource use. But can the EF be used as a guideline to achieving sustainability, or is it merely an interesting attention getting device, Costanza asks. (2000, 341)

According to the OECD (1998, 70), one of the key attractions of eco-efficiency is the emphasis placed on indicators, bearing in mind the maxim ”what's measured gets managed”. Eco-efficiency indicators can take a multitude of forms depending on their function and audience. Detailed, quantitative indicators are likely to be needed by governments to monitor environmental quality. To summarise the discussion about the development of eco-efficiency, it can be concluded that there have been several encouraging attempts to adopt the eco-efficiency concept at the product, company, industrial sector and national economy levels during the late 1990s. Furthermore, it seems obvious that the general "gain over cost" method for calculating efficiency is the best suited basis for eco-efficiency measures and subsequent analyses. The main difficulty in applying Daly's natural capital stock concept to the analyses is the inaccuracy of available data and the fact that the EF concept fails to take into consideration technological developments and the welfare generation process of the materials use activity. Thus, in the following eco-efficiency analysis I will focus on an analysis as outlined by the WBCSD.

3.5 The need of indicators in an eco-efficiency analysis

The use of indicators in an eco-efficiency analysis has numerous advantages as well as drawbacks. According to Braat (1991, 58), since indicators represent components or processes of real world systems, they are, in consequence of this definition, defined as models and, therefore, have all the pertinent possibilities and limitations. The numerical values of indicators tend to have special meanings to particular observers, which go beyond the numerical values themselves. For example, the number of predator birds may be used to represent the vitality of an entire forest ecosystem. The main criteria for individual sustainability indicators are that they should be quantifiable and, within limitations, should have a degree of direct or indirect predictive power.

Chambers et al. (2000, 79) state that since the emergence of nation states with their own census data and increasing statistical capabilities the use of statistics and corresponding indicators started to emerge in the late 19th century. While the search for social indicators reached its peak in the 1970s, a renaissance of indicators has swept through the sustainability debate during the 1990s. As such, the indicator approach over the last few years has been the most influential catalyst to advance debate on our future priorities. Many indicator initiatives have been successful in sparking off discussions on key future issues, highlighting trends and focusing society on its likes and dislikes. However, translating elaborate indicator reports into comprehensive public action has frustrated many practitioners, since indicators monitor macro-scale phenomena instead of individual level actions. (Chambers et al. 2000, 79)

Braat (1991, 68–69) sees that the robustness and reliability of such an indicator model can be determined by historical tests. Although system simulation models have limitations, they at least allow the use of the monitoring data for more than only retrospective evaluations of trends and policy effectiveness. On the other hand, retrospective indicators are quite useful in providing a basis for creating a better understanding of which development patterns of human-environment systems at various spatial levels can be sustained.

According to Pesonen (1999, 44), stationary economic trends were characteristic of the western industrial economies of the 1950s and 1960s, but in the 1970s this stationary situation was broken to dynamic crises when the expansive economic growth that had continued since World War II began to turn to a turbulent phase of non-growth situation where unpredictability and uncertainty factors in decision-making were dominant. Consequently, the economic forecasting that was based on linear models was replaced by new scenario models, aimed toward concretising possible and consciously constructing alternative emerging future circumstances. Basically, the scenarios include three fundamental elements, namely the definition of alternative future circumstances, the path from the present to the future and the inclusion of uncertainty about the future. Every material flow model contains at least one (base) scenario, but typically they include at least two scenarios: the base scenario "everything continues as usual" and (an) alternative scenario(s) with some changes to the first one. Wack (1985) argues that there never should be more than four scenarios because otherwise the decision-making will become unmanageable for most decision-makers. The ideal number of scenarios would be one plus two; first the surprise-free view and then two other different ways of seeing the world that focus on critical uncertainties. (Pesonen 1999, 44-45, 47)

According to Pesonen (1999, 47), there are no rules of thumb for the universal time horizons of the scenarios, but the time span of a scenario must be determined separately in each case. Factors that make it difficult to try to look too far into the future include rapid, unforeseeable changes in technology, increasing understanding of environmental sciences which may change our common truths about environmental impacts, revolutionary changes in legislation or policy, changes in the markets such as consumption patterns, supply of materials, etc. Pesonen (1999, 61) states that the results of material flow models can hardly ever be made 100% reliable because of the uncertainty of output data. The results present forecasts of the future in often very complex situations based on past data. Even the best forecasts based on one single result value can usually be interpreted as expected values of the variables presenting the future.

4 Measuring eco-efficiency indicators

4.1 Measuring the economic-environmental efficiency of an industrial society

Earlier, in Chapter 2, I made an attempt to describe the current state of affairs regarding the goals of sustainable development in economics. Much of the criticism of the mainstream economics comes from the fact that the operation of price mechanisms with respect to environmental resource use is not taken into account in current practical societal and economic policies while aiming to foster economic growth and development. The Industrial Ecology and Industrial Metabolism views seek for a full accounting of the energy and the materials flow that drive economic production and link society to the planet's grand material cycles. The growing body of work on indicators of sustainability includes a variety of material metrics. (Cleveland & Ruth 1999, 16) For measurement purposes the natural capital concept needs to be differentiated from natural income. Whereas natural capital is a stock concept, income is a flow concept.

The eco-efficiency approach presented in Chapter 3 can be used to establish a link between the economy and the environment at the company, regional and national economy levels. Several studies show that the consumption of materials, particularly in the industrialised countries, exceeds the replenishment and carrying capacity of the environment. (See, for example, Adriaanse et al. 1997 and Clarke (ed.) 1999) The general 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, that are causing damage to the life-support systems of the limited global ecosystem. The goal is to achieve a sustainable level of satisfaction of human needs (or welfare). According to Hinterberger et al. (1997, 8) the factor targets are rules of thumb giving the order of magnitude by which materials use reduction is seen as necessary.

In Section 3.3, I presented several company level measures of eco-efficiency and, in Section 3.4, previous studies about eco-efficiency at the national economy level. In their most simplified form, economic efficiency key figures express output in relation to expenses, i.e. efficiency is yield over costs. The larger this figure is, the more efficient and productive is the function concerned. When output and expenses are of the same size, then the efficiency ratio is 1. If the efficiency figure falls below 1, then the function is clearly inefficient. Schaltegger and Burritt (2000, 50) have interpreted ecological efficiency as the relationship between a measure of output and a measure of environmental impact:

$$(4.1.1) \quad \text{ecological efficiency} = \frac{\text{output}}{\text{environmental impact added}}$$

According to Schaltegger and Burritt (2000, 51) eco-efficiency is the cross-efficiency between the economic and ecological dimensions of efficiency. Eco-efficiency can be presented as follows:

$$(4.1.2) \quad \text{eco - efficiency} = \frac{\text{value added}}{\text{environmental impact added}}$$

Schaltegger and Burritt (2000, 51) state that there is no single measure of economic and ecological efficiency. The chosen measures will depend on the best information required for the purpose of the analysis. Cleveland and Ruth (1999, 15) argue that a common indicator of the intensity of materials use is the quantity of material used per unit of economic output (for details see Cleveland & Ruth 1999, 19–24), i.e. weight of materials per GDP. The indicator of the GDP/TMR ratio has been advocated by many researchers as the one to best describe the development of eco-efficiency at the national level. However, the OECD (1998, 41) sees that because of several limitations of this ratio, especially its inability to give a full impression of the trends and causes of specific environmental pressures, no single measure can be advocated to describe eco-efficiency at the national level, since the measurements need to evolve over time and the preferred indicators depend on the national circumstances and aims. Consequently, a large number of indicators has been created to measure the achievement of eco-efficiency, all seeking to describe the realisation of the objectives imposed. (OECD 1998, 41)

According to the OECD (1998, 39) societal scale eco-efficiency thinking needs different types of goals and indicators. Most analyses are based on standardised physical or monetary output indicators, such as volume produced expressed as value added. At the national level, the most common indicator is the GDP. Obviously, these indicators cannot capture the full complexity of societal goals, such as the Factor 10 target (OECD 1998, 60). In addition to conventional economic indicators, eco-efficiency points towards the need to consider ”quality of life” and ”human needs” when considering the ”output” indicator of eco-efficiency at the national level. According to the OECD (1998, 40) economic indicators of welfare include the GDP, green GDP and other income distribution indicators. Indicators describing the satisfaction of basic needs include the UN's Human Development Index (HDI), which is one of the best known attempts to construct a single indicator of quality of life. The denominator or input side of eco-efficiency at the national level can be formed by environmental pressure indicators or state of the environment indicators. Pressures on the environment include emissions of different pollutants, consumption of unrenewable and renewable natural resources, economic valuation of environmental damage and the use of environmental services. State of the environment includes remaining mineral resources, concentrations of pollutants in different environmental domains, indicators of biodiversity, ecological footprints and natural capital.

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. Improvements in the quality of life can be indicated by indices that are more closely introduced in Sections 4.3, 4.4. and 4.5.

4.2 Material flows as a measure of environmental stress

The inadequate functioning of the price mechanism, the underpricing of natural resources and the totally missing prices of numerous environmental services are the main reasons why other means have been developed to meet the need for indicators of environmental impact to also be utilised in eco-efficiency analyses. Thus most of these means, developed within the ecological economics school of thought, are not based on the common market pricing mechanism, but on natural resource or material flow analysis instead. They are specifically targeted toward evaluating the natural resource use and the nature resource productivity of the economies in the industrialised countries. The most important of them is the endeavour to supplement the economic concept of efficiency by Material Flow Accounting (MFA) and Material Flow Analysis and their derivatives so as to improve the materials efficiency of production systems. The general objective of these approaches is to help in steering the society "to produce more from less" (also known as qualitative growth), i.e. minimising natural resource use and at the same time maximising welfare.

The Rio Conference in 1992 fostered once again the development of the materials balance approach and the subsequent tools and methods which trace their roots back to the ideas and experiments of the 1960s and 1970s. (See Boulding 1966 and Ayres et al. 1969) Even though the benefits of the materials balance analysis were already known in the early 1970s, the introduction of this technique has been delayed by a debate on how to combine in an expedient manner the information which it provides with the system of national accounting, and by a shift in attention away from the exhaustion of natural resources and towards global environmental threats. Generally, Alfieri and Bartelmus (1999, 33) distinguish three main approaches to materials balance accounting:

(a) natural resource accounts (NRA),
(b) physical input-output tables (PIOT) and,
(c) material flow accounts (MFA).

In the 1970s and 1980s, the principal application of the materials balance approach was in Natural Resource Accounting, or NRA, which begins by monitoring the size and use of environmental or natural resource reserves. Bartelmus (1989, 80–81) states that in the early 1970s the United Nations Statistical Office employed Robert Ayres to develop a comprehensive Materials-Energy Balances Statistical System, or MEBSS, but when the methodological elements of the project had been completed in 1978, the United Nations Statistical Commission decided that such an approach would only be serviceable in the long term and did not recommend its adoption since countries still lacked the necessary statistical capabilities. Thus, apart from the energy balance approach, the MEBSS was never applied in practice. Since the early 1970s, the leading European countries in this work have been Norway and France. The first framework for natural resource accounting in Norway was compiled in 1968 and a more sophisticated version followed in 1971. The first complete system of natural resource accounting was completed in 1981. After this, however, as global environmental problems began to occupy the centre stage, interest began to slowly shift away from developing material flow and natural resource accounting and towards monitoring the environmental impacts that are the worst from the point of national economies and to expressing these in financial terms.

Natural resource accounts (NRA) are measured in physical units such as weight, volume, energy equivalent or area, and are largely consistent with the asset accounts of the System of National Accounts (SNA). The PIOT present material flows from, and back into, the environment in great sectoral detail, providing a balance of total material inputs and outputs. These tables can also be interpreted as material-energy balances (MEBs). The current material flow accounting (MFA) attempts to measure the material "throughput" through the economy as a measure of the sustainability of economic activity in physical terms. They may include ecological rucksacks of hidden material flows that are not physically incorporated in a particular output. (Alfieri & Bartelmus 1999, 33) Material flow accounts may also be compiled when the size or scope of the environment or natural resource reserves are not precisely known.

During the 1990s, pioneering work was carried out by the German Wuppertal Institute on the adoption of Material Flow Accounting (MFA) techniques for monitoring the overall amounts of materials, mainly fossil energy sources, i.e. the material flows, used in national economies. Nation-wide statistical analyses of materials consumption were also compiled. Besides Germany, this approach was applied in the USA, the Netherlands and Japan in 1997 by the World Resources Institute (USA), the Netherlands Ministry of Housing, Spatial Planning and Environment (The Netherlands) and the National Institute for Economic Studies (Japan). In 1996–1998, the European Union also supported the Pan-European ConAccount (Concerted Action on Material Flow Accounting) research project headed by the Wuppertal Institute and aiming to further develop the MFA practices in Europe. Since the 1990s, the MFA has constituted one of the centrepieces of current ecological economics. It was only towards the end of the 1990s when material flow analyses gained a new, additional perspective entitled eco-efficiency.

The modelling and calculation work of the Wuppertal Institute to monitor the technosphere, or economy, as a whole, was based on the laws of thermodynamics referred to in Chapter 2 and particularly on the theoretical work of Kenneth Boulding and Herman Daly. The basic idea is that of transforming the primary materials derived from the natural environment through the processes of the technosphere into waste for ultimate disposal. Where the earlier material flow examinations made in the 1970s and 1980s and in the early 1990s, such as the "Limits of Growth" (1972) and "Beyond the Limits" (1992) reports for the Club of Rome concentrated on monitoring the main material flows which were taken directly into the economy, the approach of others such as Friedrich Schmidt-Bleek (1994), the Factor 10 Club (1995) and Bringezu (1997) was that of reducing the total throughput of materials and energy in the technosphere. Cleveland and Ruth (1999, 34) present the basic idea behind the measurement of aggregate material use as a function (4.2.1)

$$(4.2.1) \qquad M_t = \sum_{i=1}^{N} M_{it}$$

where M_t is the weight of material i (N types) at time t.

Formula (4.2.1) describes the general principle according to which most dematerialisation analyses have aggregated the available data. It was also adopted by the Wuppertal Institute. According to formula (4.2.1) all materials of different qualities are added up to the approximate environmental stress they finally result in. Thus it is possible to find out whether environmental stress is declining in order to see in the first place whether we face an unsustainable situation. (Hinterberger et al. 1997, 6) Furthermore, Hinterberger et al. (1997, 9) suggest caution with any weighting of material flows since they do not see any practical and convincingly superior suggestion to weighting material flows. Every material input has an ecological damage potential per se. Besides, it is not only the quality but also the quantity (scale) of throughput that disturbs ecological systems. In their final analysis Hinterberger et al. (1997, 9–11) state that the throughput or scale determines the long-term sustainability of economies and the material input, although a proxy of environmental impacts can be regarded as the only correct and available measure of scale. Hinterberger et al. (1997, 8) conclude that the aggregated material input is the only measure introduced to date which can be used to compare relative environmental impacts and which can be translated directly into the realm of economics.

The development work of the Wuppertal Institute did, in many respects, mean a return to the "original" material balance monitoring of the late 1960s and early 1970s. One new feature, however, has been the attention drawn to hidden flows, i.e. those material flows which arise when natural resources are exploited but which do not enter the sphere of economic activity and thus do not benefit the economy. This point of view is based on the MIPS (Material Input Per Service) concept, developed by Friedrich Schmidt-Bleek (1994), which uses the amount of material invested in a given service over its entire life cycle as a gross indicator of its potential environmental impact. Even though the MIPS was originally intended for evaluating individual products, processes and factories, it may also be applied to whole economies and to geographical areas. The principal concept of the MIPS is that of the ecological rucksack of a product or material, which also includes the material flows involved in its manufacture and use but which do not form part of the product or material itself.

Adriaanse et al. (1997, 1) proposed a new summary measure for industrial economy, called Total Material Requirement (TMR), which measures the total use of natural resources that a national economic activity requires. The other important measure introduced was Direct Material Input (DMI), which is the aggregated measure of the natural resource commodities that enter an industrial economy for further processing. (Adriaanse et al. 1997, 8) The DMI includes all materials used for production; the natural resources needed for energy production, auxiliary material production, infrastructures, transportation, factories, etc., in a product line. Furthermore, besides the material flows included in the DMI, the TMR also includes the hidden or indirect material flows (or ecological rucksacks of direct flows). These hidden flows (HF) are material flows or relocations of materials which are caused by the utilisation of Direct Material Inputs but which never enter the economy. (Hinterberger et al 1997, 10; Adriaanse et al. 1997, 7–8)

Along with the invention and breakthrough of eco-efficiency or natural resource productivity in general, environmental space and the Factor concepts, extensive interest arose among researchers in the mid 1990s in monitoring the overall consumption of the materials and, particularly, of the natural resources used by an economy. Within the European Union, the first Eurostat (Statistical Office of the European Communities) conference to monitor the material balances of national economies was organised in March 1995. These natural resource and substance accounts, compiled by statisticians, have been produced in Europe by the national statistical institutes of Austria, the Netherlands, Germany, Norway and Sweden. National economy material flow accounts, covering a large number of materials with widely varying environmental impacts, have mainly been compiled by European ecological economists since the mid-1990s. The ConAccount (Co-ordination of Regional and National Material Flow Accounting for Environmental Sustainability) co-ordinating project on material flow accounting and analysis was set up with European Union support (1996–1998) in order to co-ordinate the interest felt in this matter. The aim of the project has been to promote research and co-operation between researchers pertaining to material flows and to establish links with decision-makers. (For further details see Bringezu et al. 1998) The project had a major influence on the development of national economy MFAs in Europe. Associated examinations were also conducted into the use of materials in certain industrialised societies, e.g. the USA, Japan, the Netherlands and Germany.

In 2000 a follow-up study to the Wuppertal Institute's research work was conducted on the material outflows of the above mentioned countries and Austria in order to learn more about the potential environmental burden of material flows. (See Matthews 2000, 6) Domestic Processed Output (DPO) refers to the total weight of materials extracted from domestic environment and imported from other countries to be used in domestic production which then flow to the domestic environment. Domestic Hidden Flows (DHF) refer to the total weight of the materials moved or mobilised in the domestic environment for economic use which do not themselves enter the economy. Total Domestic Output (TDO) is the sum of DPO and DHF, representing the total quantity of material outputs to the domestic environment. (Matthews et al. 2000, 7)

4.3 Measuring the welfare of a society

In Section 4.2, I suggested that the nominator (value-added) of eco-efficiency formula (4.1.2) should represent “the improvement in quality of life” that includes a wide variety of social phenomena of which many are not measurable. The relevance and choice of these social indicators depends on the social goal and performance being evaluated. The originally Scandinavian tradition focuses on the presumption that material and social benefits provide different opportunities for society or people that can be turned to different qualities of lifestyle. (Dieren 1995, 145–146) Thus it is important to first take a closer look at the concepts of welfare or well-being, in practice often used interchangeably, and at their measurement. The closer look in Section 4.4 is focused on other “quality of life” indicators" which also take into account other, non-monetary social phenomena.

According to Dieren (1995, 143) welfare is a state derived from the satisfaction of wants or needs evoked by our dealings with scarce means, and well-being is a state derived from the satisfaction of wants or needs evoked by our dealings with scarce means and non-economic factors. Well-being, thus defined, therefore includes welfare but goes even beyond it. Thus, welfare is an economic concept that can be measured and presented in monetary terms. The first attempts to correct purely economic indicators towards welfare indicators were based on the neoclassical welfare theory and several welfare indicators were constructed in practice in order to estimate more correctly the development of welfare in societies. Hinterberger et al. (1997, 11) use service units as a proxy for “well-being” and define sustainability as meaning non-declining number of services per person per year over time. However, well-being can be de-linked from services if more and more people find that well-being is not necessarily connected with consumption. The measurement of such services has its own problems and limitations. Thus, this Section focuses on those economic aspects of welfare that are more easily measurable.

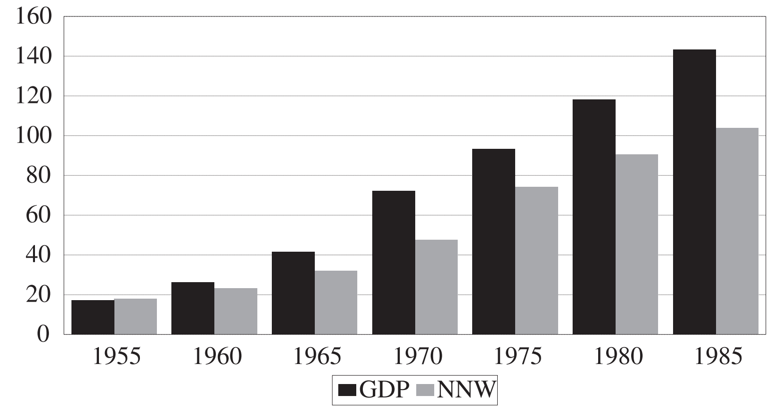
According to Costanza and Daly (1997, 66–67), the concept of sustainability is implicit in the definition of income (following Hicks), so natural income must also be sustainable (according to Daly’s rules). Economist John Hicks (1939, 172) formulated the idea of sustainable income that even today forms the core of the policy of sustainable development. Hicks defined man’s income as the maximum value which he can consume during a week and still expect to be as well off at the end of the week as he was at the beginning of it. Sustainable income is thus, according to Hicks, the amount people can consume without impoverishing themselves. This Hick’s definition of sustainable income corresponds closely with the definition of sustainable development of the WCED report (1987). Atkinson et al. (1999, 20) argue that the monitoring of sustainable development goes beyond establishing whether the key component of welfare, i.e. consumption per capita, is preserved. The critical issues concern the degree to which this consumption entails the consumption of assets, both natural and man-made. Simple indicators of consumption cannot answer these questions. Instead, integrative measures of sustainable development must attempt to embrace these aspects.

Economists have long recognised the fact that the GDP is misleading as an indicator or even as a proxy of the welfare of a nation, let alone as a measure of people's well-being, although the makers of economic policy commonly think to the contrary. (See e.g. Chambers 2000, 10) This problem already became apparent in practical economic policies in most industrialised countries in the early 1970s. The most famous examples of this development are the MEW index developed by Nordhaus and Tobin in 1972, the Japanese NNW indicator in 1973, the EAW index of Zolatas in 1981, the ISEW indicator of Daly and Cobb in 1989 and the UN's Human Development Index, or HDI, in 1990. They are all based on neoclassical welfare economics and use as the starting point the System of National Accounts (SNA) and one of its economic indicators, the GDP. The basic idea behind all these approaches is the inclusion of nonmarket commodities in an aggregated macroindicator in monetary terms as the neoclassical theory demands.

The Measure of Economic Welfare (MEW), developed by Nordhaus and Tobin, aims to measure the positive contribution of the economy to social welfare. Nordhaus and Tobin begin with the conventional GNP measure and make three types of adjustments: reclassification of the GNP expenditure items as consumption, investment and intermediate; imputation for the services of consumer capital, leisure and product of household work; and correction for some of the disamenities of urbanisation. First, consumption must be separated from investment and intermediate expenditure. This is because the GNP is a measure of production, whereas economic welfare is a matter of consumption. This entails the deletion of depreciation, as is already accomplished in the Net National Product (NNP) of the SNA. Because welfare correlates with per capita consumption rather than with gross consumption, in order to sustain per capita consumption for a rising population some portion of the NNP must reinvested. Second, appropriate imputations must be made for consumer capital services, leisure and nonmarket work. The latter two have a major effect on statistics and there is no indisputable method for valuating them. Third, Nordhaus and Tobin recognise the negative "externalities" connected with economic growth and suggest that these are most apparent in urban life. (Daly & Cobb 1989, 76–77)

In Japan the need for quantitative measurement of the state of welfare led to the estimation of the Net National Welfare (NNW) by the Japanese government in 1973. The aim was to answer the question of whether economic growth contributed to the improvement of economic well-being or not, what contributions economic growth brought to the quality of life and what kind of policy helped to increase welfare. The NNW indicator is actually a Japanese label for the MEW proposed by Nordhaus and Tobin. As such, the NNW is derived as a sum of (a) NNW government consumption, (b) NNW personal consumption, (c) services attributable to household-related social overhead capital, (d) services attributable to personal durable consumption goods, (e) leisure time, (f) extra-market activities such as housewives' domestic services, etc., (g) (deduction) environmental pollution and (h) (deduction) loss due to urbanisation. Generally speaking, the NNW is a modification of the GDP and it only includes elements that can be somehow translated into monetary value. Since 1955 the values, then almost equal, of both the GDP and NNW have risen, but the growth of the NNW has been considerably slower than that of the GDP. The progress of the NNW and GDP in Japan is presented in Figure 4.

Figure 4.
Progress of NNW and GDP in Japan 1955–1985 (JPY billion, 1970 prices)



Source: Uno 1989, 310.

As can be seen from Figure 4, the Japanese GDP and NNW have followed very much the same upward trend although the NNW has lagged behind since the mid-1960s and has since remained permanently at a lower level than the GDP. In Japan, the welfare losses caused by pollution reached their absolute and relative peak in 1970. During the 1970–1975 period the average annual growth of the NNW was 9.3 per cent, whereas the annual growth of the GDP remained at 5.2 per cent. In fact, the growth of welfare continued although due to the oil crisis the economy slowed down to a recession. In the 1980s the rate of growth of the GDP was also higher than that of the NNW. The welfare loss attributable to environmental pollution hit the peak in 1970, both in absolute figures as well as in its ratio to the NNW which amounted to 14.3 per cent. By 1980, the loss caused by pollution was reduced to 4.3 per cent and by 1985 to 3.0 per cent of the NNW. (Uno 1989, 307–310)

Zolatas (1981, 43–44) constructed an Economic Aspects of Welfare index (EAW) to depict the full range of the actual changes in a society's quantifiable well-being, regardless of weather or not they were the outcome of market transactions. Compilation of the EAW index is mainly based on national income accounts, and particularly on private consumption, which has the most direct bearing on a society's well-being. Zolatas then deducts from private consumption the value of durable consumer goods, advertising, natural resources, rapid growth and the rising social cost of environmental pollution, as well as the cost of commuting and private health and education outlays of investment of corrective nature. In addition, he adds to private consumption the services from the stock of public capital, services from durable consumer goods, household services, and leisure time and public sector services related mainly to expenditure on education and health. For the non-market factors, like household work and leisure time, the values are imputed. According to Zolatas (1981, 101–103) the EAW index, applied to the United States for the period from 1950 to 1977, shows that the economic aspects of social welfare are a diminishing function of economic growth in industrially mature, affluent societies. The percentage increases in social welfare over time are smaller than the corresponding increases in the GDP, and are diminishing. When the elasticity of the EAW/GDP ratio reaches zero, economic welfare will have attained its maximum value. Beyond that point any further increase in the GDP would lead to an absolute decline in economic welfare.

One especially ambitious effort to combine the conventional SNA and the enlargements proposed by the MEW, NNW, EAW and ISEW indicators was started by Roefie Hueting, of Statistics Netherlands, in 1974. The objective of the development work became the adjustment of national accounting according to the values assigned to the most important environmental changes. This work produced what was known as the NAMEA matrix (National Accounts Matrix with Environmental Accounts) in the late 1980s. The NAMEA matrix incorporated all environmental data into national accounts in a systematic manner. The development of the model exploits one of the principle components of national accounting: the principles of investment-yield accounting and the idea of material balance. In principle it is possible to gather a large variety of supplementary environmental data pertaining to national accounting and combine these data in the form of accounts of the impacts of economic activities on the environment. The ultimate goal of the NAMEA system is to produce “accounts of affluence” according to a neoclassical theory of affluence in which the values of environmental damage are deducted from the value of the net national product. One problem, however, is the pricing of environmental and natural resources, meaning that it is not possible to express all environmental data in financial terms. Difficult environmental evaluation problems in the NAMEA model are bypassed by using indicators. The biggest shortcoming of the NAMEA system is that in its present form it fails to make any allowance for the use of natural resources. The Statistical Office of the European Communities, or Eurostat, does not consider it expedient to include material flows in the NAMEA system because this would over-inflate the system.

While the above mentioned enlargements of the Keynesian national accounting practices with monetarised environmental information can be regarded as modest efforts, some ecological economists have widened the scope of welfare even more radically. For example, according to Daly and Cobb (1989, 70) the entire GDP cannot be consumed without eventual impoverishment, so in order to find out the economy’s “income” in Hick’s sense, the depreciation must be subtracted to get the green Net National Product. However, the original NNP cannot be consumed without impoverishment, as the production of the NNP at the present scale requires ecologically unsustainable environmental extractions and insertions and because the NNP overestimates the net product available for consumption by counting the defensive expenditure required against the unwanted side-effects of production as a final product. Daly and Cobb (1989, 71) define the corrected Hicksian income (HI) concept as NNP minus defensive expenditure (DE) and depreciation of natural capital (DNC) as an equation (4.3.1):

(4.3.1) $$HI = NNP - DE - DNC$$

Consequently, Cobb and Daly express the ISEW index by using the equation (4.3.2):

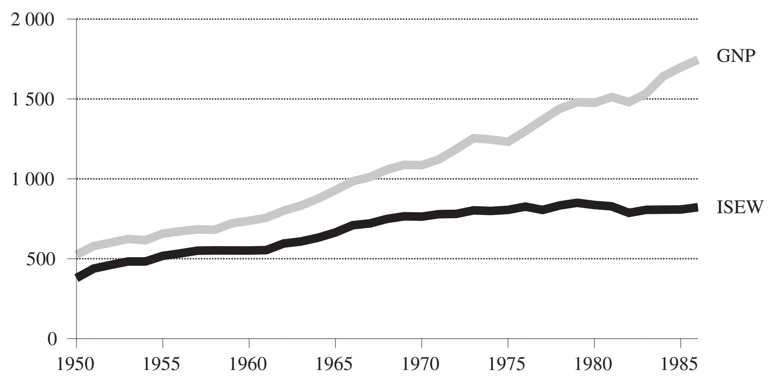
(4.3.2) $$ISEW = C_{adj.} + P + G + W - D - E - N$$

where $C_{adj.}$ is consumer expenditure adjusted to account for income distribution, P is non-defensive public expenditure, G is growth in capital and net change in international position, W is estimate of non-monetarised contributions to welfare, D is defensive private expenditure, E is costs of environmental degradation and N is depreciation of natural capital. A rising path of the ISEW over time will indicate that an economy is becoming more sustainable. In the same way, a rising green NNP is claimed to indicate increasing sustainability. A falling path will indicate the opposite. (Hanley et al. 1999, 60) Figure 5 presents the progress of the ISEW and GNP in the United States from 1950 to 1986. The calculation of the ISEW was done by Cobb and Daly (1989, 416–443).

As can be seen from Figure 5, the in the USA the growth of total economic welfare (measured by ISEW) vanished after the 1970s although the GNP has continued to grow. In fact, the economic welfare of an average American (economic welfare per capita) has even decreased after the 1970s although the GNP has continued to grow. According to Cobb and Daly's calculations the external effects of production and the inequitability of income distribution are the main reasons for this development in which an increase in production does not necessary lead to an increase in welfare.

One of the most important successors of the ISEW is the Genuine Progress Indicator (GPI) developed by Cobb, Halstead and Rowe (1995) in 1994. The aim of the GPI indicator is to measure the performance of the

Figure 5.
Progress of ISEW and GNP in United States 1950–1986 (USD billion, rp)



Source : Daly and Cobb 1989.

economy as it actually affects people's lives. Furthermore, the GPI distinguishes between the benefits and costs of economic growth. The Genuine Progress Indicator takes from the GDP the financial transactions that are relevant to well-being, namely personal consumption adjusted for income inequality. The adjustments include 23 further economic dimensions of development, most of them externalities. The GPI account, with these adjustments, for the United States in 1997 is presented in Table 1.

Table 1 shows that the major difference compared to the structure of ISEW is that externalities such as crime levels, cost of family breakdowns and cost of underemployment are also included. The GPI also includes in the total production nonmarket production, such as voluntary community

Table 1.
The 1997 GPI account for United States (USD billion, 1992 prices)

Personal Consumption	4,913.5
Personal Consumption Adjusted for Income Equality	4,153.5
Adjustments	
1. Value of Housework and Parenting	+ 1,886.6
2. Services of Household Capital	+ 557.1
3. Services of Highways and Streets	+ 90.0
4. Value of Volunteer Work	+ 87.7
5. Net Capital Investment	+ 44.3
6. Depletion of nonrenewable Resources	– 1,281.6
7. Long-term Environmental Damage	– 1,012.0
8. Cost of Consumer Durables	– 668.6
9. Cost of Commuting	– 374.5
10. Loss of Wetlands	– 349.9
11. Cost of Ozone Depletion	– 306.9
12. Loss of Leisure Time	– 263.6
13. Net Foreign Lending/Borrowing	– 146.1
14. Loss of Farmland	– 127.8
15. Cost of Underemployment	– 122.3
16. Cost of Auto Accidents	– 120.5
17. Loss of Old Growth Forests	– 82.2
18. Cost of Family Breakdown	– 58.8
19. Cost of Air Pollution	– 54.2
20. Cost of Water Pollution	– 50.1
21. Cost of Crime	– 28.4
22. Cost of Noise Pollution	– 15.3
23. Cost of Household Pollution Abatement	– 11.1
NET GENUINE PROGRESS	**1,745.3**

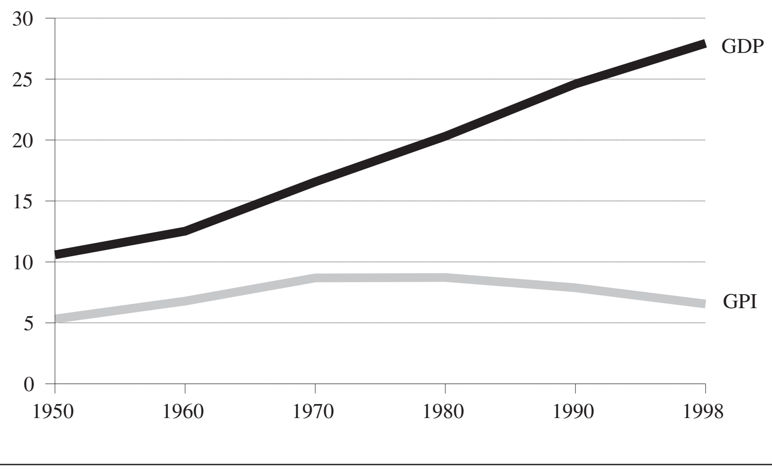
Source: Rowe & Anielski 1999, 11.

work and domestic household work. The GPI has so far been applied to the economies of Austria, Australia, Denmark, Germany, Italy, the Netherlands, the United Kingdom and the USA, although it has not been officially recognised. Figure 6 presents the progress of the GDP and GPI in the United States from 1950 to 1986. This calculation of the GPI was done by Cobb, Goodman and Wackelnagel (1999, 5–6).

As can be seen from Figure 6, the economic welfare of an average American as measured by the GPI indicator has also, like in the case of the ISEW, decreased after the 1970s although the GDP has continued to grow. The trend of the GPI clearly demonstrates how the welfare increased steadily until the 1970s, when it began to decline. After the 1970s, economic growth became uneconomical or at least a less socially desirable target than before for the majority of the people.

According to Chambers et al. (2000, 11), the GPI has two major shortcomings. First, it mixes up the social and ecological challenges of sustainability. Sustainability means quality of life to all as well as living within the means of nature and, furthermore, quality of life and nature should not be traded off against each other. The GPI also translates everything into monetary terms instead of providing a direct account of how things are. This measure fails to acknowledge the complexities associated with assigning a meaningful monetary value to many essential social and

Figure 6.
Progress of GDP and GPI in United States 1950–1998 (USD 1,000 per capita at 1992 price level)



Source: Cobb et al. 1999.

ecological services or to deal with the abstract nature of money on the whole. The fluctuation of the value of currency depends more on market whims than on social and ecological health. Thus, the GPI cannot easily express how close or how far we are from a sustainable state. Nevertheless, money is the lingua franca of the industrialised world and as long as overall measures such as GDP receive as much attention, using one that more adequately represents people's well-being is an effective step in the right direction. (Chambers et al. 2000, 11–12)

4.4 Expanding national accounts to cover the environment

While the quality of life indicators presented in Section 4.3 try to capture a wide variety of social developments affecting welfare in monetary terms, they miss most of the environmental aspects also contributing to welfare. The development of the System of National Accounts (SNA) in the 1990s has included attempts to express environmental matters in financial terms so that the information produced is comparable and capable of inclusion in the SNA figures. The ultimate objective of this development work has been to obtain a better description of the development of social affluence. This idea of monetarisation of environmental degradation and use of natural resources conforms to the ideas of neoclassical economics. Consequently, much effort has been directed during past decades to matching up environmental data with existing national accounts. According to Sheng (1995), the United Nations Environmental Programme (UNEP) was the first one to be requested in 1982 to develop methodological guidelines for environmental accounting for the developing countries. Between 1983 and 1988, the UNEP and the World Bank organised a number of expert meetings targeted towards the development of Monetary Environmental Accounting (MEA) and Physical Environmental Accounting (PEA). According to Lutz and El Serafy (1989, 88) a revision of the SNA68 recommendation was also started in the early 1980s with a number of expert groups looking at various issues and considering how improvements could be made with as little disturbance to the SNA core system as possible. However, in 1988, after five years of intensive international research and discussion, the UNEP came to the conclusion that replacing the GDP with a more sustainable measure of income was not yet feasible. Therefore, satellite accounts would be calculated which would be linked to the SNA and in which adjustments and alternative computations could be made. According to Lutz and El Serafy (1989, 88) the opinions of experts were very much divided, some arguing for radical changes towards true sustainable income while others supported gradual changes by improving income estimates into the right direction. Specific recommendations for changes in the core SNA also seemed to need resolving with respect to some conceptual issues as well as much empirical work. So, in the meantime, the creation of satellite accounts appeared the only realistic option for progress in this area. The outcome of this process, or the prototype of Environmental Accounting System, was tested in the late 1980s and early 1990s in Mexico and Papua New Guinea and, later in the 1990s, parts of the system were also compiled in Canada, Columbia, Ghana, Indonesia, Japan, the Philippines, the Republic of Korea, Thailand and the USA. The call of the Rio Conference of the United Nations to develop tools for the implementation of sustainable development policy further fostered the process. The UN Handbook on System of Integrated Environmental and Economic Accounting (SEEA) was constructed by Carsten Stahmer, Peter Bartelmus and Jan van Tongeren (see Stahmer et al. 1993) with the support of the United Nations Statistical Office, UNSTAT, and the World Bank and subsequently published in 1993. The SEEA handbook presented an overview of the various concepts and methodologies of environmental accounting that had been discussed and applied during the past years. One of the main tasks of the handbook was to synthesise the approaches of the different schools of thought in the field of natural resource and environmental accounting. (Dieren 1995, xvii, 232,233, 265)

SEEA accounts, which allow for the exploitation of data on natural resources and environmental damage when calculating the value of production, were explicitly created as a policy instrument of sustainable development. In practice, however, achieving a consensus on the pricing of environmental damage and the use of natural resources proved to be politically impossible in the USA in the mid-1990s and no Environmental Accounting in monetary terms was realised. Today, defining the green GDP is even more clearly regarded by the researchers in the field as an unattainable ideal. The SEEA system, currently under revision, 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 natural sciences, with no link to economic activity. At the same time, the responsibility for developing environmental accounts is increasingly being transferred from social scientists to natural scientists.

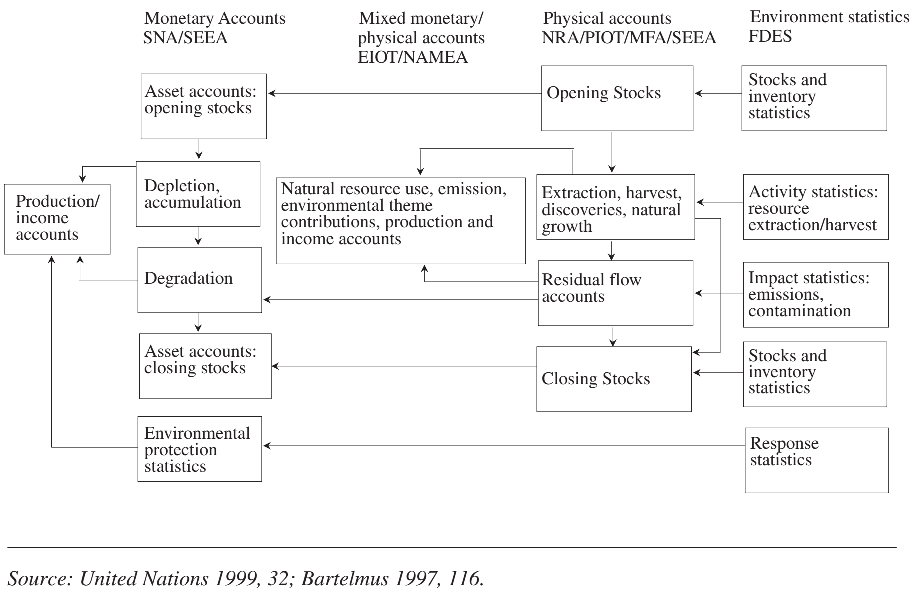
Formula (4.4.1) was also the basis of the Environmentally adjusted Domestic Product (EDP) of the United Nations SEEA presented in 1993. Dieren (1995, 236) derives the eco (green or environmentally adjusted) domestic product concept that SEEA also uses as follows:

(4.4.1) GDP – DF = NDP – DN = EDP

where GDP is gross domestic product, DF is depreciation of produced fixed assets caused by economic activities, NDP is net domestic product and DN is depreciation of non-produced fixed assets caused by economic activities. Dieren (1995, 236) states that the Hicksian income concept was developed at a time when there had not been any urgent worldwide and long-term environmental problems. That is why some experts hesitate to apply this concept in the case of environmentally adjusted domestic product, although others advocate it.

The SNA uses two concepts to describe economic performance, the Gross Domestic Product (GDP), which shows the value added produced by all institutional units resident within a country, and the Gross National Income (GNI), which reflects the aggregate value of their primary income irrespective of whether it has been earned in the country or abroad. Because it seems impossible to include a description of the economic-environmental interrelationships of the residents outside the geographical area and exclude those of the non-residents within the geographical territory, the SEEA uses the concepts of domestic product and national income. Figure 7 below describes how different environmental statistical systems and accounts link together.

Figure 7.
Linking statistics and environmental accounts



Source: United Nations 1999, 32; Bartelmus 1997, 116.

The System of Integrated Environmental and Economic Accounts (SEEA) was designed to combine economic and environmental information. In practice the SEEA combines the data from national accounting with existing environmental and natural resources data and serves more as a supplement to, rather than a replacement for, traditional national accounting. The SEEA also includes what is known as the "green GNP", but calculation of this requires data on environmental changes. As there are no market prices for most of the commodities provided to mankind by the environment, the biggest problem with the implementation of the SEEA soon appeared to be finding the "right" price structure for natural resources and the environment. In the United States, the adoption of the SEEA was strongly favoured by the Clinton administration and subsequent development of the SEEA was started by the Bureau of Economic Analyses (BEA), operating under the Department of Commerce, in April 1994. However, soon the strong opposition reaction of market forces, afraid of losing their economic decision-making indicators like GDP and GNP and having an artificial price put on their raw materials, lead to a halt of finances for the environmental account compilation work and the project remained unfinished. In Europe, the idea of the implementation of the SEEA lived a little longer in the EU Member States and the EFTA countries, although no country started their own SEEA project. In 1995 these countries still believed that the monetary values of their natural resource assets would be included in their national balance sheets within the next 2–3 years. However, lack of consensus about the valuation methods and of comprehensive statistics on the environment and natural resources brought the implementation of the SEEA into a halt in Europe, too, in 1996–1997.

Despite the halt in its practical implementation, theoretical development of the SEEA continued in the so called London Group on Environmental Accounting that was founded in 1993 to provide an informed forum for the practitioners of the SEEA in statistical institutes and international organisations for sharing their experiences of developing and implementing environmental satellite accounts linked to the economic accounts of the System of National Accounts. The Group has members from the United Nations, World Bank, OECD, EU Commission, the United Kingdom, Germany, France, the Netherlands, Italy, Switzerland, Denmark, Norway, Sweden, Finland, Austria, the United States, Canada, Australia and Japan. The London Group, named after its first conference city in 1994, has convened in meetings on a yearly basis. The ensuing discussions on frameworks and analyses revealed substantial differences in conceptual approaches – some originating from historical development and others from emerging or current trends. For example, the Dutch National Accounting Matrix including

Environmental Accounts (NAMEA) emphasised accounting for emissions in physical terms, organised under thematic headings. The issue of sustainable use of natural resources has influenced other countries to move towards the framework of the SEEA. There was a general agreement that the frameworks are broadly consistent and the choice of framework depends on the desired emphasis. Usefulness of the "Green Domestic Product" and green aggregates received mixed reception. For some, the underlying issues were too complex to be represented by a set of aggregates. For others, the difficulties in establishing sound underpinnings (e.g. valuation challenges) and attaining agreement on appropriate approaches implied that it is still too early in the collective experience to commit to such measures.

The 1995 meeting revealed widespread movement among the participants to adopt the SNA93 recommendations with respect to the broader definition of the balance sheet. All countries (except the United States) were on course to include monetary values for their natural resource assets in their national balance sheets in future. However, there was still little consensus on valuation methods. Furthermore, most countries were working to develop links between physical material flow and waste output accounts to traditional input-output accounting systems. Valuation remained at the forefront of the discussions as participants grappled with the thorny issues of valuing resource depletion, determining total costs of environmental protection and assessing the worth of environmental goods such as clean air, water, etc. From among the discussed topics a few were identified for additional research and for the future agenda. These included intended use and applications of the monetary and physical accounts and accounting for resources with multiple and complementary uses (such as forests).

After disagreements on the valuation methods for nonmarket environmental commodities among economists and policy makers as well as due to the UN's lack of resources, the London Group of national accountants received in 1997 a task to prepare a revised SEEA. The trend in the development seems at the moment to be towards an independent accounting system that is separate from national accounting. This means that problems of valuation can be bypassed, but at the cost that the interaction between the environment and the economy will not be included. However, the new recommendation will not exclude the possibility of estimating sustainable national welfare. Indeed, international organisations, like the UN, OECD and World Bank, as well as the USA have all been strongly in favour of such "green" GDP. The main topics to be included in the new SEEA recommendation are environmental protection expenditure, use of natural resources, environmental taxes and ecoindustries. The London Group aims for the revised SEEA, now also known as SEEA 2000, to become an internationally agreed manual or handbook of the best practices for implementing green accounting. The handbook will be presented to the Statistical Commission of the UN in 2001 and subsequently published by the UN, OECD, Eurostat and World Bank.

The operating manual of the SEEA (Alfieri & Bartelmus (ed.) 1999, 2) states that "the need to account for the environment and the economy in an integrated way arises because of the crucial function of the environment in economic performance and in the generation of human welfare. These functions include the provision of natural resources to production and consumption activities, waste absorption by environmental media and environmental services of life support and other human amenities." Alfieri and Bartelmus (1999, 41) devised equation (4.4.2) to define an Environmentally adjusted Domestic Product (EDP) identity for the entire economy as the sum of Environmentally adjusted Value Added of industries EVAi with a further deduction of Environmental Costs generated by households (ECh):

$$(4.4.2) \quad EDP = \sum EVA_i - ECh = NDP - EC = C + CF - CC - EC + X - M$$

where EVA_i describes the Environmentally adjusted Value Added generated by an industry i and includes fixed Capital Consumption (CC) and Environmental depletion and degradation Costs (ECi),
ECh is the Environmental depletion and degradation Costs of households,
NDP is the conventional National Domestic Product of the SNA,
EC is Environmental depletion and degradation Costs,
C is final Consumption,
CC is fixed Capital Consumption,
CF is Capital Formation,
X is export and,
M is import.

Basing on equation (4.4.2), different alternative indicators adjusted for natural resource depletion, or both depletion and environmental degradation, can be compiled depending on the valuation technique used and its scope and coverage. At the moment the draft version of the SEEA 2000 states that "Some authors consider that environmental protection expenditure is 'defensive expenditure' and is only the cost of 'maintaining environmental well-being' or keeping natural capital intact and, as a result, should not be included in the NDP. This concept does not form part of the SEEA. However, one way of using environmental protection accounts is to model the effects of assumed changes in environmental protection measures in order to estimate the way such changes will affect economic activity, growth and employment in the future. A specific use of such a model might be to estimate the effect on the GDP of a given level of environmental protection measures."

According to the neoclassical economic theory, besides the environment, such elements as unpaid household production and leisure time should also be included in sustainable income. Between 1997 and 1999 a pilot study financed by Eurostat (Statistical Office of the European Communities) was undertaken by Statistics Finland to develop a harmonised satellite system of household production. The final report of the study outlines a proposal for a satellite account of household production which could provide an overall picture of the productive activities undertaken by households and give an estimate of the value of nonmarket household production. The satellite account of household production includes the value added of household production, the value of work, and the value of capital goods used in household activities. So far, the valuation forms the biggest problem in the development of a Satellite Account for Household Production. The project report recommends that the valuation should be based on the input method (through costs). (Varjonen et al. 1999, 3, 7) As a result, on the basis of the pilot study Eurostat aims to start developing methods for producing Satellite Accounts for Household Production in near future. This development process would ensure the commensurability of emerging Satellite Accounts in different countries.

4.5 Other "quality of life" indicators

Attempts to monitor the environmental changes caused by human activities were started by scientists and statisticians already in the early 1970s. However, their success has so far remained very limited in scope. According to Bartelmus (1989, 80–81), facing these problems in 1972–1973 the Conference of European Statisticians of the Economic Commission for Europe (ECE), inspired by the UN Conference on Human Health in 1972, decided in 1973 to take the initiative to develop a system of environmental statistics that would complement the already existing System of National Accounts (SNA) and the System of Social and Demographic Statistics (SSDS) established in 1975. However, it soon became apparent that the current state of knowledge about the environment and its statistical measurement, as well as the widely differing environmental concerns and priorities, did not permit an internationally applicable statistical system to be established. Therefore, in 1984 the United Nations Statistical Office developed a flexible Framework for the Development of Environmental Statistics (FDES). Since the FDES lacked statistical definitions and classifications, no direct linkage was established with the SNA or any other statistical system. Consequently, the FDES has remained as a blueprint rather than an operative statistical framework. The developing of material flow and balance accounting has also suffered from a similar problem. According to Clarke (1999), despite the fact that the United Nations established the Framework for the Development of Environmental Statistics (FDES) already in 1984, shortage of an information basis of sustainable development remains a major obstacle to the implementation of the policy of sustainable development even today. The existing FDES is by its very nature an "unsystematic" accounting system and provides no sufficient methods for sorting out environmental data. For example, the UNEP (Clarke 1999) recognises lack of relevant data as the common experience within the environmental domain. There are serious data gaps related to, for example, pesticide application, the state of fish stocks, forest quality, groundwater and biological diversity. In addition to the data gaps, the poor quality of the existing data is of equal concern today.

Besides economists, social and natural scientists have also started in the 1990s to develop methods for collecting and presenting accurate scientific information about the environment at a more aggregated level, as e.g. physical indicators, such as sustainable development or environmental indicators. Their point of view is the well-being of people and/or living nature, or as they usually put it, the state of the world or the environment. Although in some cases these indicators lack connections to economic data, they do manage to describe some vital dimensions of development often bypassed by economists. This angle has been supported for example by Desai (1993, 27–28), who sees that the current search for a measure of social well-being originates precisely from the welfare economics of Pigou (1929) and thus the current disagreements about the measure among economists are in fact about the "machine" that generates well-being from commodities or income, about which commodities to include and which to exclude, their relative weights, the extent to which income alone can be said to capture this or whether we need a vector of disparate elements (not necessarily excluding income) to capture the constituent elements that feed into the machine that generates well-being. Consequently, several indices have been designed that offer solutions to these problems of selecting and weighting different commodities produced by economy or offered directly by nature. In practice these approaches have been utilised by various international bodies like the United Nations' UNEP and CSD, the OECD, World Bank and European Union, as well as many individual countries at the national and regional levels.

Partly thanks to these pioneering efforts, the information basis of sustainable development has improved significantly during the 1990s. For example, the UNEP (Clarke 1999) recognises that some global and regional compendia of environment-related data have improved the global stock of data resources considerably. Notable examples of this are the Dobrís data compilations in Europe and the World Bank's World Development Indicators. In addition, a small but steadily growing number of countries has set up systematic compilations of environmental data, in part following the guidelines of the United Nations Statistical Office (UNSTAT). This is resulting in national environmental reports being issued by more countries, and in gradual improvement and harmonisation of the reporting to the Commission on Sustainable Development (CSD) and within the frameworks of multilateral environmental agreements. The relatively widespread testing by countries of the CSD indicator methodology may well see the demand for input data developing and becoming more concrete.

Since the Rio Conference in 1992, the UN's Commission on Sustainable Development (CSD) has also been preparing indicators for monitoring the progress towards sustainable development. The Indicators of Sustainable Development (ISD) are targeted to assist decision-makers and policy-makers and to increase focus on sustainable development. Beyond the commonly used economic indicators of well-being, however, social, environmental and institutional indicators have to be taken into account as well, in order to arrive at a broader, more complete picture of societal development. A working list of 134 indicators and related methodology sheets has been developed and is now ready for voluntary testing at the national level by countries from all regions of the world. The aim of the CSD with respect to the ISDs is to have an agreed set of indicators available for all countries to use by the year 2001. The aim is a flexible list from which countries can choose indicators according to national priorities, problems and targets. The indicators are presented in a Driving Force – State – Response framework. The "Driving Force" indicators indicate the human activities, processes and patterns that impact on sustainable development. The "State" indicators indicate the "state" of sustainable development while the "Response" indicators indicate policy options and other responses to changes in the "state" of sustainable development. The social, economic, environmental and institutional aspects of sustainable development are covered by this list of indicators following the chapters of Agenda 21.

The United Nations Environmental Program (1998, 14–15) has published Global Human Development Reports since 1990. The Human Development Index (HDI) measures the overall achievements in a country in three basic dimensions of human development: longevity, knowledge and a decent standard of living. It is measured by life expectancy, educational attainment (adult literacy and combined primary, secondary and tertiary enrolment) and by adjusted income expressed in Purchasing Power Parity (PPP). The HDI is focusing on the people and thus it provides an alternative to the view of development equated exclusively with economic growth. It sees economic growth and higher consumption not as ends in themselves but as means for achieving human development. The components of the HDI and its derivatives, such as Gender adjusted Development Indicator (GDI), Human Progress Indicator for developing countries (HPI-1) and Human Progress Indicator for industrialised countries (HPI-2), are presented in Figure 8.

Atkinson et al. (1999, 137) argue that in many respects the HDI's focus on education and health reflects the "basic needs" philosophy of development. This philosophy emphasises the roles health, education, food, public transport, housing sanitation and water have in solving poverty problems. The implication of this thinking is that governments should provide these goods and services before considering the more traditional investments in

Figure 8.
Human Development Indicator and its derivatives

Index	1. Longevity	2. Knowledge	3. Decent standard of living	4. Participation or exclusion
HDI	Life expectancy at birth	1. Adult literary rate 2. Combined enrolment ratio	Adjusted per capita income in PPP, USD	–
GDI	Female and male life expectancy at birth	1. Female and male adult literary rate 2. Female and male combined enrolment ratio	Adjusted per capita income in PPP, USD, based on female and male earned income shares	–
HPI-1 For developing countries	Percentage of people not expected to survive to age 40	Adult illiteracy rate	1. Percentage of people without safe water 2. Percentage of people without access to health services 3. Percentage of underweight children under five	–
HPI-2 For industrialised countries	Percentage of people not expected to survive to age 60	Adult functional illiteracy rate	Percentage of people living below the income poverty line (50% of median personal disposable income)	Long-termun employment rate (12 months or more)

GDI = Gender adjusted Development Indicator,
HPI-1 = Human Progress Indicator for developing countries, and
HPI-2 = Human Progress Indicator for industrialised countries.

Source: UNDP 1999, 127.

manufacturing and infrastructure. Although Atkinson et al. (1999, 138–142, 146) consider that the HDI is without a question probably the most successful modern development indicator, yet they also list shortcomings of the HDI. First, the HDI is a relative measure, not absolute, which makes it impossible to carry out comparisons across countries. Second, the HDI is incomplete, because it only consists of some variables relevant to the measure. Third, the HDI is criticised for its selection of indicators that could be better, for example because some indicators double count some developments.

5 Practical eco-efficiency analysis of the Finnish economy

5.1 Starting points for an eco-efficiency analysis covering a whole economy

The eco-efficiency approaches and, in particular, the eco-efficiency analysis and its linkages to ecologically sustainable development or sustainability, are examined more closely in this Chapter. The GDP, EDP, ISEW and HDI indicators, also presented in the previous Chapter, will also be utilised in the eco-efficiency analysis that follows. Since the indicators used in the study 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.

Combining material flow accounting with national accounting data is in theory viewed as a clearly progressive step. Such a reform is hampered, however, by the diverse theoretical bases of these systems, which have prevented their combination into a single system. As stated in Section 4.1, the OECD (1998, 41) sees that no single measure can describe eco-efficiency at the national level since measurements and preferred indicators depend on national circumstances and aims. Consequently, a large number of indicators can be created to measure the achievement of eco-efficiency. In Sections 4.2, 4.3 and 4.4, I introduced several indicators that can be utilised in an eco-efficiency analysis. The “output” or “value-added” side can be represented by the GDP, EDP, ISEW, GPI and HDI indicators and the “input” or “environmental impact” side by the TMR, DMI, NPP, ecological footprint, environmental space and other aggregated environmental indices.

From the point of view of eco-efficiency, different dimensions or interpretations of these indicators must be kept in mind. For example, Hanley et al. (1999, 57) classify the indicators of sustainable development into three major groups, namely: 1. economic, 2. ecological (environmental) and 3. socio-political. The first group includes such measures as Green Net National Product (green GDP) and Genuine Savings, the second one includes

Net Primary Productivity (NPP), Environmental Space and Ecological Footprints (EF) while the third contains Index of Sustainable Economic Welfare (ISEW), Genuine Progress Indicator (GPI) and Human Development Index (HDI). From the point of view of sustainable development, these indicators can be divided into weak (WSD) and strong (SSD) measures of sustainability. According to Hanley et al. (1999), for example, most authors would describe the green NNP and Genuine Savings as weak measures, whilst Ecological Footprints might be considered a strong measure. Compared to Hanley's division, the eco-efficiency indicators can thus receive different contents as to the scale of sustainability depending on the welfare and environmental impact or state of the environment indicators used in the analysis.

The listed indicators of environmental impacts or state of the environment all provide quite generalised pictures of their issues. In international studies, the commonly used measures of environmental impacts have been several material flows measured in tonnages (weight). However, although this approach seems to be most commonly used and the most favourable, it should be kept in mind that it also has several limitations. For example, the summation of various material tonnages into a single measure provides a very rough picture of the state of the environment. From the 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 the 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 DMF and TMF measures to be compiled and used.

Cleveland and Ruth (1999, 16) list further general shortcomings that have been used to counter argue the explanation power of statistical dematerialisation studies. First, measuring aggregate materials use in terms of weight and then comparing it to the GDP has little economic meaning, since weight is only one of the many attributes that users consider when choosing materials. Thus, it is claimed that weight is an inappropriate basis for the aggregation of materials. The second argument is that many analyses of dematerialisation do not explicitly represent demand, technological change or structural change and do not use methodologies that can test for the presence and relative strength of these forces. The third argument is that the techniques used to test for trends in time series and cross-sectional data often lack statistical rigor. Most of the above mentioned observations are undoubtedly true. However, the monetarisation problem can largely be surpassed by adopting the eco-efficiency analysis, which does not necessarily require the monetarisation of the "cost" or "input side". It is also true that analyses of technological and structural change remain excluded from the eco-efficiency analysis in the sense that they are not analysed separately as driving forces. Whereas in many countries there is no data available on materials flows, in Finland the available material flow database is comprehensive and its statistical accuracy and relevancy are also high.

In this Chapter I use the conventional Gross Domestic Product (GDP) and other measures of welfare per Direct Material Flow (DMF) ratios in an empirical analysis to estimate the eco-efficiencies of certain industrialised economies. The Eco-efficiency 1 is defined as the GDP per DMF ratio, Eco-efficiency 2 as the EDP1 per DMF ratio, Eco-efficiency 3 as ISEW per DMF ratio and Eco-efficiency 4 as HDI per DMF ratio. The classification into Eco-efficiencies 1, 2, 3 and 4 stems from the welfare indicator used in the corresponding eco-efficiency ratio. Eco-efficiency 1 can on this basis be called the *Eco-efficiency of Production,* since the GDP/DMF ratio measures the direct benefits (gross flow of gains from economic and natural capital) received from production per material input used in the processes. The EDP/DMF ratio measures the actual benefits generated by production and available to society (net flow of money from economic and natural capital) per material input used in the processes. Eco-efficiency 2 can be named the *Industrial Eco-efficiency* of society. Eco-efficiency 3, reviewed through the ISEW/DMF ratio, comes closest to the idea of true improvement of life per material input used by measuring the net flow of benefits from production actually received by individuals (gross flow of gains from economic and natural capital distributed in society). Thus the ISEW/DMF ratio can be regarded as the *Societal Eco-efficiency*, as it also takes into account the environmental and income distribution dimensions of well-being in addition to economic well-being. However, the fact that only the external effects of production and development, i.e. the negative developments in the environment, are included while the human development dimension is almost totally excluded, makes the ISEW, as well as the ISEW/DMF ratio, incompetent measures of actual well-being. The HDI/DMF ratio or Eco-efficiency 4 measures the *Human Eco-efficiency* (the increase of human potential to improve current state of life), hence the HDI is a relatively good measure of economic and societal well-being. However, the HDI overlooks totally the environmental dimensions of development, as well as the indirect impacts of negative developments on the environment, which are also crucial to human beings in the long run.

In the following study I used Finnish and international data to perform an eco-efficiency analysis and to evaluate the potential use of the method in macro level sustainability evaluations. This severely constrains analyses as well as the development and testing of new methods for analysing the material bases of industrialised economies. In Finland, however, a suitable database on material flows and welfare accounts has been compiled recently at the national level, enabling us to extend the eco-efficiency analysis from the conventional GDP per materials use composition to a more advanced analysis. Thanks to the Finnish material flow accounting, well advanced by international standards, it is possible to examine and develop advanced empirical methods, such as the eco-efficiency analysis, that can be used in evaluating economy-wide sustainability. By analysing the progress in materials use in relation to several welfare and quality of life indicators, it is possible to learn more about eco-efficiency and its measurement for further research and development.

As stated in Section 4.1, a large number of indicators have been preferred to be developed for measuring the achievement of eco-efficiency. The chosen measure will depend on the best information available for the purpose of the analysis. (See e.g. Schaltegger and Burritt 2000, 51) The OECD (1998, 41) also sees that the preferred indicators should depend on national circumstances and aims. Thus in the following Sections I aim to first present the trends of environmental degradation in Finland; second, present data concerning the output side of the eco-efficiency analysis, namely the relevant welfare indicators, as well as the relevant input side data, namely the Finnish DMF and TMF data; third, describe the actual eco-efficiency analysis that can be formulated on the basis of the available data, and fourth, perform the division of Finnish eco-efficiency into sectoral analyses.

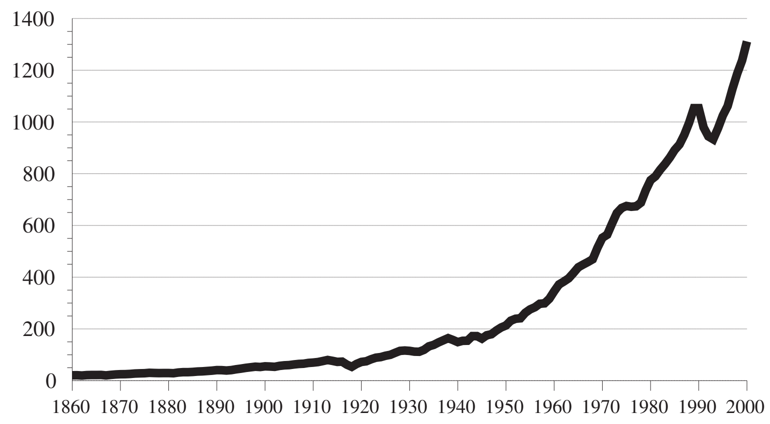
5.2 Development of human caused environmental concerns in Finland

The Finnish economy has always been largely dependent on the productive capacity of renewable resources and has sought to adapt means of production to the regenerative capacity and scarcity of the ecological system (eg. see Kuisma 1997, 226–227). As recently as in the 1850s, despite its abundant forests and fields Finland was still in a position were its population was incapable of self-sufficiency, let alone capable of producing surplus to the world markets. Although the main source of livelihood was agriculture, it was already possible for industry to develop. The main obstacles in many areas were high birth and mortality rates, poor productivity of work, underdeveloped division of labour and insignificant existing capital stocks. However, in Finland public administration and education were fairly well organised, living conditions were peaceful and industrialisation was beginning. Together with the economic reforms pushed through in the 1860s these factors formed fairly good preconditions for industrialisation and rapid economic growth. While Finland's Gross National Product was some 25 per cent below the average European level in the 1860s, by World War I Finland had come up to the average European level. (Hjerppe & Pihkala 1989, 22)

Between the World Wars economic growth in Finland was two times higher than the average European level and thus, in 1938, the Finnish GNP per capita was over 30 per cent above the average European level. After World War II Finland lagged somewhat behind the average economic growth until 1973, when it exceeded it. (Hjerppe – Pihkala 1989, 22–23) In the 1970s and 1980s, Finland ascended to among the ten wealthiest countries in the world by conventional indicators. This development of the volume of the Finnish GNP is depicted in Figure 9 and in Statistical Appendix 1.

The extensive post-war reconstruction after the Second World War and the industrialisation of the late 1940s and 1950s were based especially on the forestry and engineering industries. Rapid industrialisation was possible because of the availability of natural resources, cheap hydroelectric power and a relatively well-educated labour force. Industrialisation was, in fact, speeded up because of the war reparations that had to be paid to the Soviet

Figure 9.
Trend in the volume of GNP at market prices (1926=100)



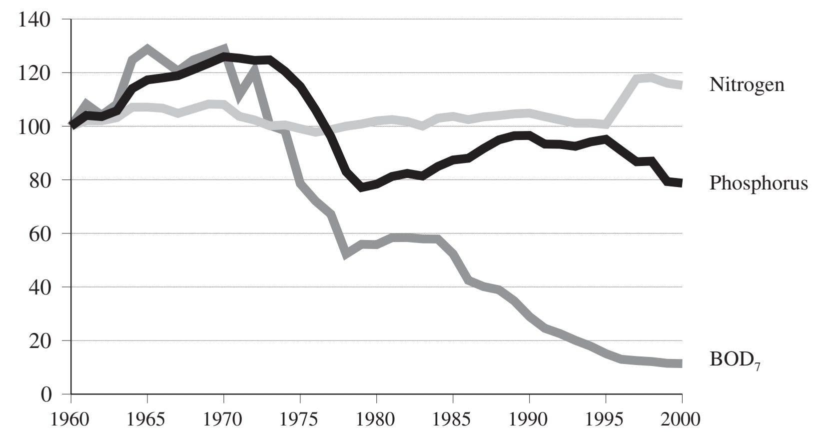
Source: Statistics Finland.

Union. Some 75 per cent of them were paid in engineering industry and one quarter in forest industry products. Thus a higher proportion of the national economic resources were directed into the engineering sector than would have been the case without the war reparations, and the country developed a large and modern engineering industry. Consequently, the economic backbone of the nation was built around industries exploiting forest resources and cheap energy, such as the pulp and paper industry, basic metal industry and engineering manufacturing sector. Even though the structure of Finnish industry has diversified since the 1960s and 1970s and the importance of the electronics sector in particular has increased during the 1990s, the forestry and basic metal industries are still widely regarded as the backbone of the country's economy. Today, the Finnish economy, and particularly the export industries which sustain national affluence, are also strongly based on the exploitation of natural resources and fossil fuels.

The very first efforts to develop policies for nature conservation and water management in Finland were made already at the turn of the 20th century. (See e.g. Haila & Jokinen (eds.) 2001) However, the post-war industrialisation, forced by the war reparations, was for a long time supported unanimously by the whole population. It was generally reckoned that industrialisation would automatically bring prosperity and recreate the country as a modern, welfare society. Thus, the local environmental drawbacks from 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. However, the striving for extensive economic growth practised in Finland especially since the 1950s soon caused environmental problems and developed into a common concern among the population in the early 1970s. As society's response, the first major efforts were focused on water pollution control. This progress was highlighted by the setting up of the National Board of Waters under the Ministry of Agriculture and Forestry in 1970, and by drawing up the first water pollution control plan in 1974. In the 1970s Finnish environmental policies were marked by a case-by-case and pragmatic approach with strong public support and by the introduction of cleaner technologies in the replacement and development of the capital stock of several industries. Progress in areas such as water quality was made with respect to organic pollution, improved management of municipal waste and extended protection of outstanding natural areas. However, the progress was limited in scope and a number of problems remained or were emerging. (Haila & Jokinen (eds.) 2001, 32–33, 66; OECD 1988, 81)

The economic growth that Finland underwent in the 1970s and early 1980s was faster than the average growth in the European OECD countries and resulted in pressures being imposed on the Finnish environment that were above the Nordic, Western European and OECD averages. Subsequently, in the early 1980s, the growing pressures on the environment from economic activities and impacts of transboundary air pollution, together with strong public opinion demanding environmental protection, led the Finnish authorities to strengthen the policies aiming toward protecting human health, preventing unacceptable damage to the environment and ensuring sustainable use of natural resources. Consequently, the Ministry of the Environment was established in October 1983. In October 1986, the National Board of Waters was renamed the National Board of Waters and the Environment under the authority of the Ministry of the Environment. However, the authority over water administration remained with the National Board of Waters and the Waters under the supervision of the Ministry of Agriculture and the Forestry. These reforms launched a comprehensive effort to consolidate and strengthen environmental protection in Finland. Subsequently, many existing laws and institutional practices were re-examined and updated. (See e.g. Haila & Jokinen (eds.) 2001, 66; OECD 1988, 81) The progress of Finland's aquatic discharges is depicted in Figure 10 and in Statistical Appendix 2.

Figure 10.
Trends in Finland's aquatic discharges in 1960–2000 (1960=100)



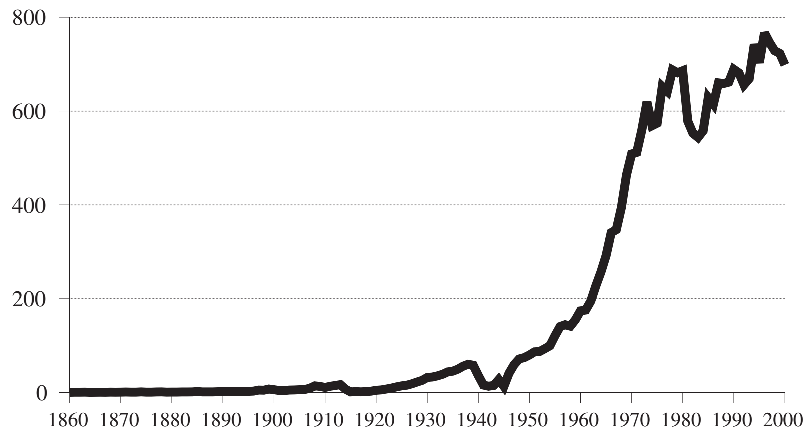
Source: Finnish Environment Institute.

Human-caused aquatic discharges, originating from agriculture, industry, fish farming, households and aerial deposition, have decreased considerably since the early 1970s, as shown by Figure 10. Biological oxygen demand (BOD_7) also continued to decrease during the 1980s and 1990s. However, nitrogen and phosphorous emissions stabilised in the late 1980s and 1990s. Further reductions to aquatic emissions are demanded by the Government's programme of water pollution objectives. According to the programme, which was approved in March 1998, the nitrogen and phosphorus emissions of the industrial sector are to be reduced by 50 per cent, and the chemical oxygen demand (COD) by 45 per cent, from the 1995 level by the year 2005.

One of the major interests of the Finnish environmental policy in the 1980s was the protection of ambient air. Wood and cheap hydroelectric power were the principal energy sources in Finland right up to the end of the 1950s. In the post-war period, however, cheap oil flooded the world market from new and plentiful discoveries of oil in the Middle East and Africa, which could be exploited at low cost, and conquered the Finnish energy market. Since the structure of Finland's economy developed strongly dependent on high levels of energy consumption although domestic energy sources were limited, from the 1960s on cheap imports of fossil fuels, oil and coal from abroad ensured the continuation of the industrial progress. The use of wood as an energy source declined during the 1960s as all growth in energy consumption was taken up by oil which, by the end of the 1960s, met more than half of Finland's energy needs. The range of available energy sources began to diversify only after the first oil crisis in 1973–1975. In the 1970s four nuclear reactors were constructed in Finland and a gas pipeline was built to Russia in the 1980s. These new energy sources reduced oil consumption considerably. Where in the 1950s some 70 per cent of Finland's energy needs had been met from domestic sources, by the end of the 1970s the domestic proportion had settled at 30 per cent and it has, with minor fluctuations, remained at this level throughout the 1990s. (Laaksonen 1989, 68–72) This progress is depicted in Figure 11 and in Statistical Appendix 1.

Despite the sharp rise in the use fossil fuels, depicted in Figure 11, and apart from some local air pollution problems, the air quality remained generally fairly good for a long time. This can be credited to the fact that Finland is a sparsely populated country and is located on the northern edge of Europe, away from major industrial areas. Consequently, from the 1960s through to the early 1980s, air pollution control was practised in Finland on a voluntary basis. It was not until 1982 that the Air Pollution Act was instituted. (OECD 1988, 140) Finnish emissions of sulphur dioxide (SO_2) peaked in the 1970s and those of oxides of nitrogen (NO_x) in the 1980s and early 1990s. However, in the 1980s and 1990s, Finland made several inter-

Figure 11.
Total consumption of fossil fuels in Finland 1860–2000 (Petajoules)



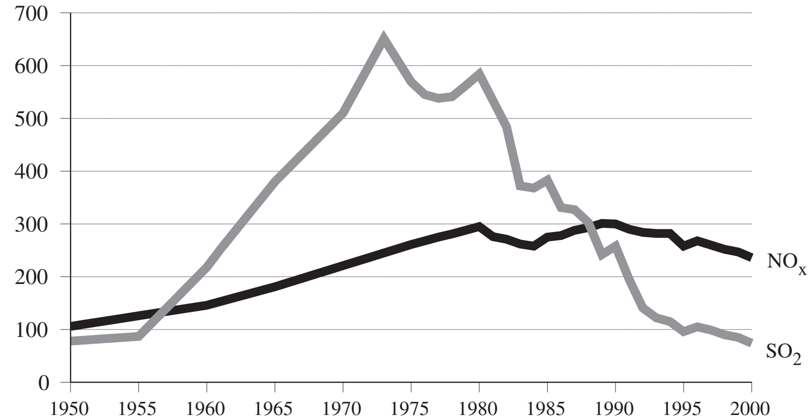
Source: VTT Energy and Statistics Finland.

national commitments to reduce its transboundary emissions in the near future. In 1988 Finland committed to freeze its emissions of oxides of nitrogen to the 1987 level by the end of 1994 and announced an intention to reduce them by 30 per cent from the 1980 level by 1998. Similarly, in 1994 Finland committed to cut down its sulphur emissions by 80 per cent from the 1980 level by the year 2000. In practice, emissions of sulphur dioxide decreased in the 1980s and 1990s so that in 2000 they were the same as in 1950. In 2000, the emissions of oxides of nitrogen had decreased by 19 per cent from the 1987 level. (Hoffrén 2001, 60) The development of sulphur dioxide (SO_2) and nitrogen oxide (NO_x) emissions (as NO_2) in Finland is depicted in Figure 12 and in Statistical Appendix 3.

As can been seen from Figure 12 the reduction in sulphur dioxide (SO_2) emissions has been remarkable and the emissions of oxides of nitrogen (NO_x) have also stabilised during the 1980s and 1990s. Partly as a result of this development the yearly acid deposition has also diminished considerably in Finland. However, in 1997 only some 22 per cent of the acid deposition caused by sulphur, as well as some 20 per cent of the acid deposition caused by nitrogen, in Finland were of Finnish origin. This progress of the total annual depositions of sulphur dioxide and nitrogen oxides in Finland is depicted in Figure 13 and in Statistical Appendix 3.

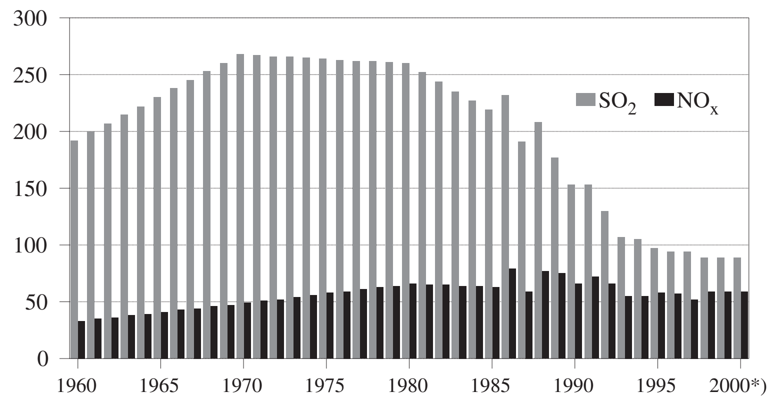
As depicted in Figure 13, the pressure from acid air pollution on the Finnish environment has relaxed since the early 1980s. This development owes

Figure 12.
Sulphur emissions (SO_2) and emissions of nitrogen oxides (NO_x) in 1950–2000 (thousand tonnes)



Sources: *1950–1979: National Board of Waters and the Environment; Ministry of the Environment. 1980–2000: Statistics Finland.*

Figure 13.
Yearly acid depositions of sulphur dioxide (SO_2) and nitrogen oxides (NO_x)



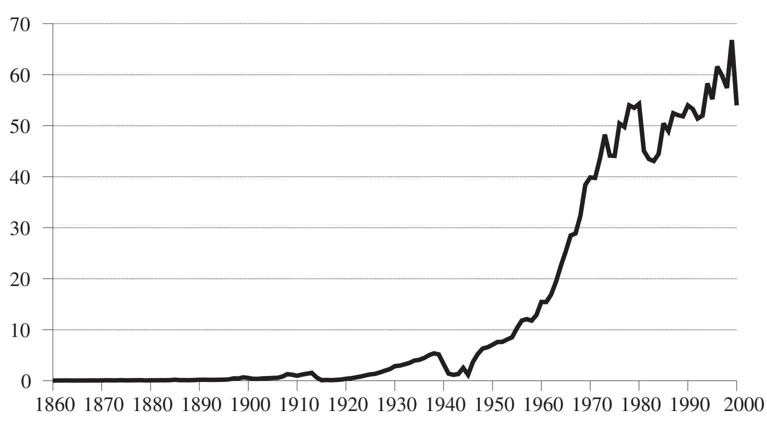
*) = estimate.

Sources: *1950–1979: National Board of Waters and the Environment; Ministry of the Environment. 1980–2000: Statistics Finland.*

much to the international environmental agreements signed in the 1980s. Basing on data on the depositions of sulphur and nitrogen, the Finnish Environment Institute has estimated the overruns of critical loads in Finland. Critical load defines the amount of acid deposition the specific local soil and water ecosystems can sustain without long-term damages. According to these assessments, the overall picture suggests that, in spite of favourable deposition trends, critical loads are still being exceeded in certain parts of Finland.

Besides acid air pollution problems, sharp rise in the use of fossil fuels has also contributed to the global climate change that became a major concern of international environmental policy in the early 1990s. Climate change and reduction of carbon dioxide (CO_2) emissions only became environmental policy issues in Finland after the UN's Conference on Environment and Development in Rio de Janeiro in 1992. The targets for greenhouse gas emission reduction, agreed at the UN Climate Meeting in Kyoto in December 1997, were assigned to each of the EU Member States in Luxembourg in June 1998. Finland agreed to reduce its greenhouse gas emissions to the 1990 level by the years 2008–2012, on condition that the EU takes efficient steps to implement measures, such as energy taxes, affecting all the Member States. Eighty-four per cent of Finland's greenhouse gas emissions are carbon dioxide. Finland's carbon dioxide emissions from energy generation totalled 54 million tonnes in 2000, i.e. they had decreased by three million tonnes from the previous year. (Hoffrén 2001, 44) The carbon dioxide emissions were the same as in 1990, or the baseline year. The progress of total carbon dioxide emissions in Finland is depicted in Figure 14 and in Statistical Appendix 1.

Figure 14.
Carbon dioxide emissions from fossil fuels and peat in 1860–2000 (million tonnes)



Source: VTT Energy.

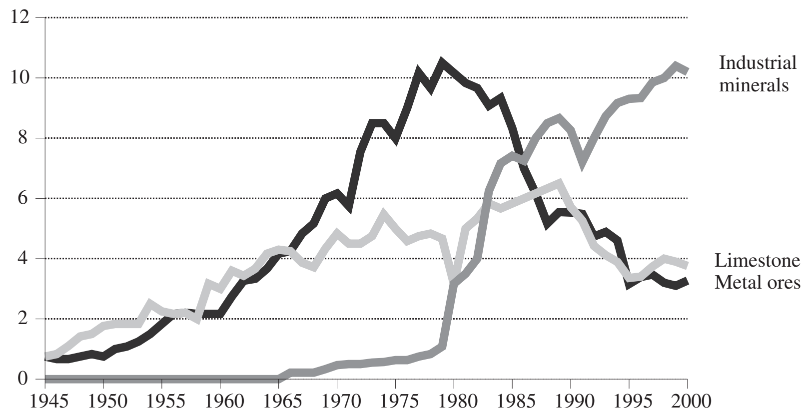
Finland’s national climate strategy was completed in March 2001, when the Finnish Government also presented it to the Parliament. The strategy emphasises that Finland’s greenhouse gas emissions will exceed Kyoto targets unless determined efforts are taken to combat this trend. The strategy also notes that greenhouse gas emissions are crucially dependent on economic growth, the structure of the economy and the structure of the electricity sector. To achieve the Kyoto objectives, actions are needed in energy production and consumption, transportation, the construction sector, community planning, control of agricultural and forest industry emissions as well as in waste management. Actions are also needed in research and development, the development of economic policy instruments (such as taxation and subsidy policy, regulations and ordinances), voluntary agreements and the promotion of consumer initiative. (Hoffrén 2001, 8, 44–45)

It was not until the late 1990s that some attention was paid in the Finnish environmental policy to the volume of natural resources use. Until recently the sufficiency or scarcity of natural resources was seen as a more or less economic problem, or one that related to the biodiversity of nature. This viewpoint originated from the fact that Finland’s economically most important natural resource has throughout history been forests. In the 18th and 19th century, however, forests were exploited in a manner that almost completely destroyed valuable timber in the near vicinity of settlements. Since the 1920s the use and care of the forests has been based on the idea of sustainable timber production forestry, which ensures the timber volume is upheld.

Even though large-scale exploitation of timber resources is quantifiably sustainable, a recent OECD country study (1997, 24) has pointed out that forest management is the main reason for the loss of biodiversity in the Finnish ecosystem. As quantifiably sustainable forestry has been practised and deposits of iron ore and other minerals have also been relatively scarce in Finland, no active environmental policy measures have been targeted towards the use of natural resources. The progress of mining of ores and industrial minerals, and quarrying of limestone in Finland is depicted in Figure 15 and in Statistical Appendix 4.

According to Figure 15, the mining of ores and quarrying of limestone already reached their peaks during the 1970s and 1980s and now these mines are rapidly closing as their known reserves, which were relatively small, are mostly exhausted. As Finland has a modern, competitive metallurgical industry, further processing of metals can be expected to continue for a long period of time, albeit depending to a great extent on imported raw materials and recycling. The mining of industrial minerals is still at a high level as it was started relatively late. The utilisation of ores, minerals and limestone has been free and supported by the state. Consequently, the utili-

Figure 15.
Mining of ores and industrial minerals and quarrying of limestone in 1945–2000 (million tonnes)



Source: Mining Industry Association and Ministry of Trade and Industry.

sation of Finnish non-renewable resources has been done without any co-ordinated natural resource management or general aims targeted toward minimising their use.

However, especially the minimisation of natural resource use is a vital part of the policy of sustainable development. According to the decisions made by the Rio Environment and Development Conference, all countries must have a sustainable development strategy by the year 2002. In Finland the Government established the Finnish National Commission on Sustainable Development in June 1993, chaired by the Prime Minister. The work of the Commission aims at promoting the implementation of sustainable development in Finland in accordance with the decisions made in Rio in 1992. The National Commission on Sustainable Development set up a network of different ministries and organisations in October 1996 to co-ordinate the development and testing of indicators. The Finnish sustainable development strategy was approved in June 1998, and Finland was one of the first countries to establish a policy. According to its main objectives, the policy is, among other things, committed to slowing the climate change process, moulding production and consumer habits, reducing the use of non-renewable natural resources, and maintaining biodiversity. The objective with respect to production and consumer habits is to reduce the strain on the environment caused by production and consumption to a level tolerable to nature, and to promote the effective use of natural resources in the production of goods and services. The Finnish Committee on Sustainable Development published a list of national indicators for sustainable development in spring 2000 (see Rosenström & Palosaari 2000). The relevant administrative sectors and other entities will report to the committee on the implementation of the sustainable development programme by summer 2001. Drawing on the reports by the various administrative sectors and other investigations and development projects, the Finnish Committee on Sustainable Development will compile an overall evaluation of the effectiveness of Finland's sustainable development programmes and the state of sustainable development in Finland. This evaluation is scheduled for completion by the time of the World Summit on Sustainable Development in 2002, the follow-up to the Rio Environment and Development Conference. (Hoffrén 2001, 7–8; Hoffrén 1999a, 6–7)

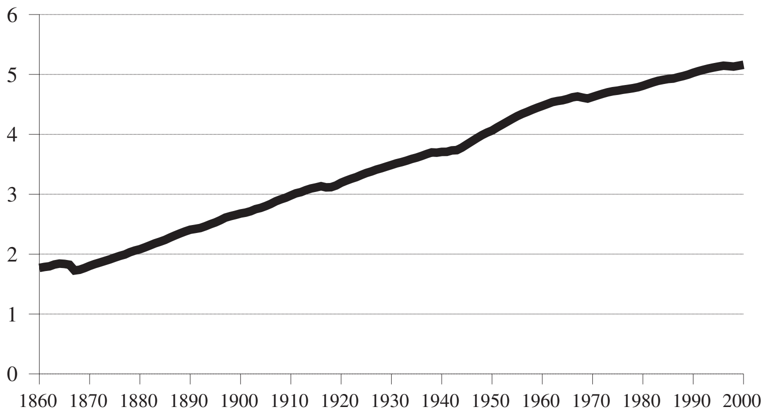
5.3 Development of welfare and "input" indicators in Finland

As stated in Chapter 4, various indicators of welfare can be utilised in depicting the development path of a society. Hanley et al. (1999, 57) regard the Green NNP and Genuine Savings as weak measures, whilst Ecological Footprints represent a more or less strong measure. The indicators of sustainable development belonging to the second group, i.e. environmental indicators of sustainable development, are mostly determined by the size of population. The trend of population size in Finland is depicted in Figure 16 and in Statistical Appendix 1.

As can been seen from Figure 16 the growth of population was high in the 19th century and in the first part of the 20th century, but since the 1970s the growth has been one of the lowest among the industrialised countries at only some 0.3 per cent per year. As the population size is quite stable in Finland, indicators based on a specific space or land area somewhat fail to provide an overall picture about the development of welfare, since they exclude vital factors such as technological progress and international trade.

Chapter 4 presented the various methods of measurement with which the trend of the overall eco-efficiency can be viewed at the whole economy level. The DMI concept introduced by the Wuppertal Institute, and presented in Chapter 4, includes besides material flows also the consumption of water and air. However, for simplicity I use the name "DMF indicator" for the DMI indicator from which water and air have been excluded because of the inaccuracy of estimations of these resources. The Direct Material Flow (DMF) and Total Material Flow (TMF) indicators, developed and used by

Figure 16.
Population in Finland 1860–2000 (million)



Source: Statistics Finland 1998a.

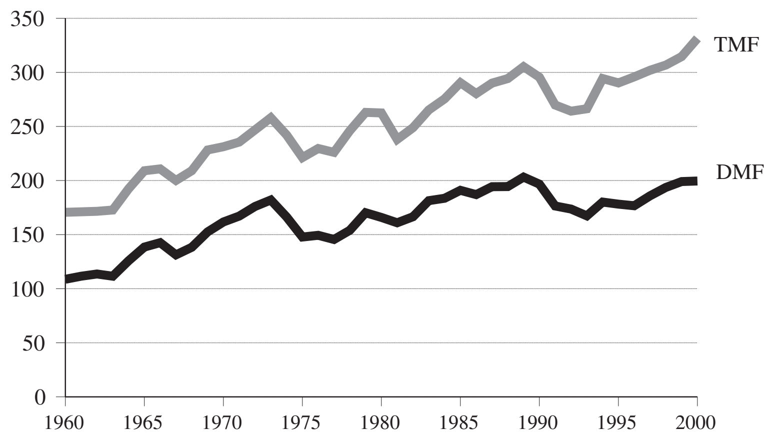
ecological economists, are better estimates of environmental sustainability, since the materials use of an economy implicitly includes technological developments and effects of trade. The DMF indicators comprise the weight of all the materials that are taken into the sphere of the economic activities of a society, whereas the TMF also includes those materials flows, or hidden flows (HFs), caused by human economic activities that never enter the economy. These are, for example, earth and stone that are excavated in mining and quarrying and wood materials, such as branches, needles, leaves and roots, that are left in the forest in logging.

Finnish DMF time series from 1960 to 1998 have earlier been presented by Hoffrén (1997b, 1998a, 1998b, 1999a and 1999b) of Statistics Finland. For this study, these figures were revised, updated and extended to the year 2000. It should also be mentioned here that time series of the Total Material Requirement (TMR) of the Finnish economy for the years 1970–1999 were also compiled in another study conducted at the Finnish Thule Institute (University of Oulu). However, the exact numerical values of those calculations have so far not been made public, which makes comparing the two studies difficult. Nevertheless, the volumes and trends of the direct material flows (DMI and DMF) are quite symmetrical in both studies. The TMF indicator presented here is calculated on the basis of the DMF indicator by adding to it known hidden material flows and estimations of other hidden flows. The method used has been developed and recommended by the German

Wuppertal Institute. However, there seem to be great differences in the trends of the TMF and TMR. Explaining these differences would require in-depth investigations of the calculation methods and of the actual data. (See Mäenpää et al. 2000) The progresses of the Finnish Direct Material Flow (DMF) and Total Material Flow (TMF), as well as their calculation bases, are more closely depicted in Figure 17 and in more detail in Statistical Appendix 5.

The materials use of the Finnish economy presented in Figure 17 covers the largest material groups in terms of tonnage and thereby provides a fairly reliable picture of the direction of change in the direct use of materials. The materials consumption of the Finnish economy, or Direct Material Flow (DMF), comprises 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 the consumption of air and water, for which no reliable statistics are available. Beside the DMF, the Total Material Flow (TMF) also comprises so called hidden flows, or material flows that are caused by the uptake of the DMF into the use of the economy but which never reach the actual sphere of economic activities. The main problem of indicators like the DMF and TMF are that they say nothing about the achieved increase in welfare.

Figure 17.
Progress of Direct Material Flow (DMF) and Total Material Flow (TMF) in Finland (millions of metric tonnes)



The Ecological Footprint measure is also somewhat a measure of the use of the ecological productive capacity and revealing nothing about changes in welfare. Likewise, there are several difficulties relating to the estimation methods used to convert the actual commodity received by society to the land area needed to produce it. For example, according to the calculations of Hakanen (1999, 140), on the basis of the average productivity of global ecosystems, the ecological footprint of the Finns was 7.32 hectares per person in 1995. Thus, it exceeds the actual land area of Finland per person, which is only 5.95 hectares. Hakanen estimates that if a correction were to be made to the actual productive capacity of the Finnish ecosystems, the ecological footprint would go up to 13.97 hectares per person. Besides these calculations based on the research and calculation tables of Wackernagel and Lewan (1997), Hakanen (1999, 148) has also made her own estimations according to the real productive capacity of Finnish ecosystems. According to these calculation, the ecological footprint of the Finns is only 3.34 hectares pre capita, but the existing ecological capacity is higher, 4.71 hectares per person. In that sense the so called economic indicators of sustainable development, like the Green Net National Product and Genuine Savings, give a more precise picture of the economic aspects of sustainable development.

In fact, improvement in the 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. For example, Opschoor (2000, 365) states that, from the theoretical economics side, a much more promising approach is to go for multi-dimensional indicators such as the HDI or ISEW. However, the HDI suffers from the exclusion of environmental dimensions in it, although this shortcoming could be redressed, in principle. The ISEW does include such dimensions, but they are too partial and insufficiently quantifiable to be convincing.

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 in a society, and to assist decision-making. According to a manual published by the United Nations (Stahmer et al. 1993), the EDP2 can be obtained by adding revenues from foreign production factors and indirect taxes to the GDP at market prices and by deducting from this the sum of the fixed capital consumed by environmental protection costs and other changes in the value of environmental resources. Calculation of the EDP1 mainly requires the deduction of consumption of fixed capital (man-made capital) and environmental resources (environmental capital) from the value of the traditional GDP. Consumption of fixed capital is, in practice, already accounted for in calculating the Net Domestic Product, so the only problem remaining is to compile reliable statistics about environmental protection costs and produce evaluations of changes in the stocks of natural resources and the environmental impacts of production. A calculation of the EDP time series for Finland according to the SEEA system has been presented in Appendix 8 and also earlier by Hoffrén (1997a, 103)

However, economic indicators like the EDP and ISEW, require the "right" pricing of environmental hazards in order to function properly. I base my calculations on prices already utilised by government agencies. Accurate and "rightly" priced information about actual protection expenditure is to some extent also available. Data concerning the state's environmental expenditure, along with corresponding income and environment-related taxes and fees are presented in Figure 18 and in Statistical Appendix 6.

Figure 18 shows that the revenue from environment-related taxes and fees, i.e. taxes and fees that contribute to the state of the environment, exceeded the total sum of environmental expenditure during the early 1960s. Keeping in mind that environment-related taxes and fees are not raised because of environmental reasons but because of fiscal policy objectives, they can be considered as one possible and "right" price for the environment in Finland. Another one would be the cost of fulfilling international agreements. In any case, calculation of the Environmentally adjusted Domestic Product 1 (EDP1) can now be performed for Finland on the basis of the environmental expenditure listed in Appendix 6. The progresses of the Finnish Gross Domestic Product (GDP) and Environmentally adjusted Domestic Product 1 (EDP1) are depicted in Figure 19 and in Statistical Appendix 7.

Figure 18.
Progress of environmental taxes and state's environmental protection expenditure in Finland (FIM billion, real prices)

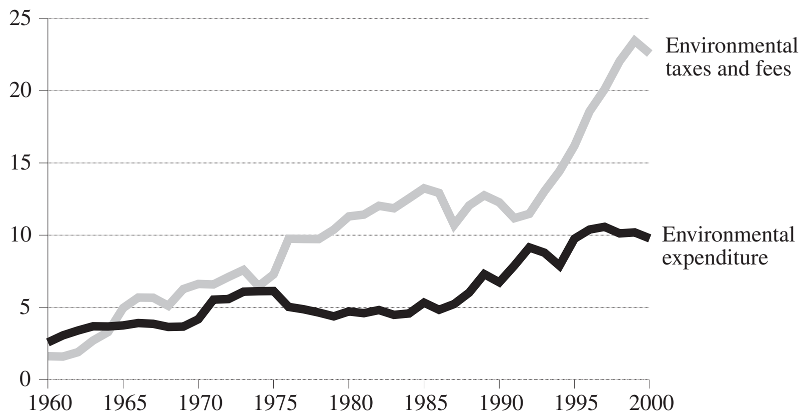
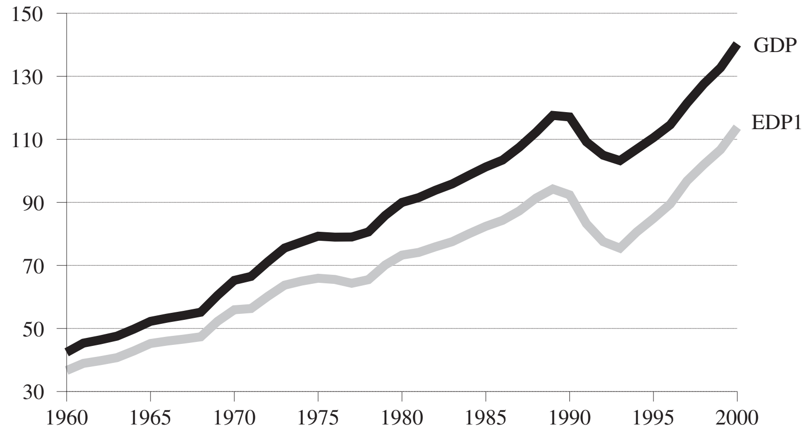


Figure 19.
Progress of Finnish GDP and EDP1 per capita (FIM 1,000, rp)



As can be seen from Figure 19, the development of the EDP1 is dominated by the GDP, which is its major component. This domination is the reason why the various “green GDP” indicators have generally been referred to as “weak” indicators of sustainable development. It should, however, be borne in mind that the EDP1 only takes into account actual environmental protection activities and excludes environmental deterioration, like air and water pollution and natural resources use. In order to expand the scope of the description of the EDP, major environmental hazards are subtracted from the EDP1 to produce the EDP2 measure. This requires pricing of those environmental changes that lack actual market prices and should, therefore, be priced using so called artificial pricing techniques.

In practice, this kind of pricing is done in Finland by Finnra (The Finnish National Road Administration) in their project assessments. Finnra has given monetary values to environmental deterioration. The very first study of the impacts of road traffic emissions and noise, as well as of their costs, was carried out in 1992. The general aim of Finnra’s assessments is to estimate the overall cost recovery of transport in Finland. The background to these assessments was fixed by the White Paper on Transport Pricing Policy of the European Commission published in 1998. The values used by Finnra were first estimated by a private Finnish company, Energia-Ekono Ltd, within the MOBILE research programme in 1994, and were since deflated according to the consumer price index. The values at the 1997 price levels are presented in the first column of Table 2 below. Previously, in 1991, the values of environmental hazards were monetarised by a Working Group set up by the Ministry of the Environment (MoE). The Group proposed specific taxes and charges on several emissions into the air and water. The unit costs were based on analyses made in 1990. They were to be introduced in 1995 and raised in 2000. However, the proposal has so far not been implemented. At the same time another Working Group set up by the MoE proposed that a tax of FIM 150 per tonne of carbon dioxide would be sufficient to stop the growth of carbon dioxide emissions. The values at the 1991 price level are presented in the second and third columns of Table 2.

The values of nitrogen oxides and sulphur dioxides presented under the heading MoE in Table 2 are based on the calculated marginal costs of attempting to fulfil the international commitments to which Finland has agreed, namely 80 per cent reduction in sulphur dioxide emissions by the year 2000 and 15 per cent reduction in nitrogen oxides emissions compared to the 1980 level. The Working Group also estimated the effective waste water charges. These are presented in Table 3.

Table 2.
Unit values of selected atmospheric emissions (FIM per tonne)

	Finnra (1998) FIM / tonne in 1997	MoE (1991) FIM / tonne in 1995	MoE (1991) FIM / tonne in 2000
Hydro carbons (HC)	10,500	–	–
Nitrogen oxides (NO_x)	5,300	10,000	20,000
Particles	95,500	–	–
Sulphur dioxide (SO_2)	6,000	10,000	20,000
Carbon dioxide (CO_2)	183	150	150

Sources: Metsäranta (1998), 59; MoE (1991), 124. *– = not in use.*

Table 3.
Proposed waste water charges (FIM per kilogram)

	MoE (1991)
Phosphorus	2,000
Nitrogen	100
COD (chemical oxygen demand)	4
AOX (organic chlorine compounds)	150

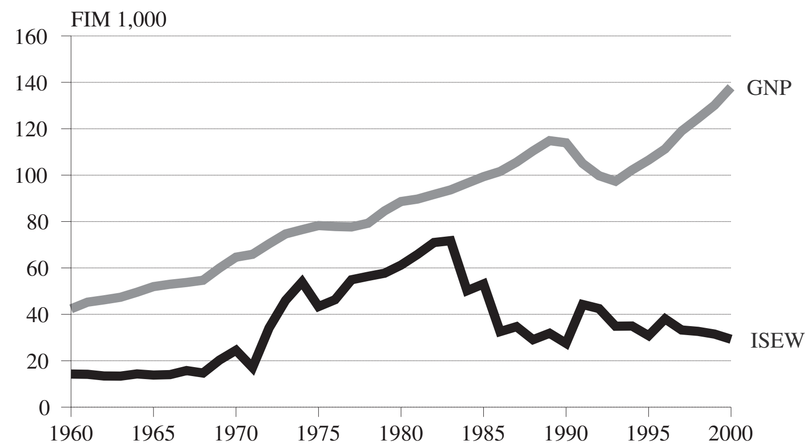
Source: MoE (1991), 127.

The prices presented in Tables 2 and 3 are based on environmental policy considerations targeted toward bringing emissions to the levels that are sustainable for the ecosystems in Finland. Furthermore, they are based on expert estimations about the environmental hazards ability to cause human health problems and environmental damages that can be monetarised. These Damage Function Approach methods include great uncertainty, making their reliability low. However, they are the only price estimates made available for Finland and are hence used in the analysis. Thus, the EDP2 measure for Finland has been constructed using the unit prices given in Tables 2 and 3 and the data on environmental hazards presented earlier in this Chapter. Data and prices used in calculating the EDP2 are presented in Appendix 8. Since the extent of environmental hazards is a consequence of the extent of industrial production, which is also the basis of the extent of economic wealth in society, the EDP2 follows quite closely the progress of the GDP, GNP and EDP1 measures. The EDP2, as well as the EDP1, are dominated by the GDP component in them. Consequently, both these EDP measures give a similar and conventional picture of the development.

The third group of indicators of sustainable development, or the socio-political indicators, like the Index of Sustainable Economic Welfare (ISEW), Genuine Progress Indicator (GPI) and Human Development Index (HDI), also take into account the social aspects of sustainable development. These approximations of welfare in society give additional information about the aggregate welfare in society. One of the most interesting of these is the concept of the ISEW, the Index of Sustainable Economic Development, developed by Daly and Cobb (1989, 401–455), and its further derivatives, such as the GPI, or the Genuine Progress Indicator. According to Castaneda (1999, 237), in addition to the United States ISEW, there have been six other attempts to implement the ISEW. Namely in the UK (Jackson & Marks 1994), Germany (Diefenbacher 1994), the Netherlands (Rosenberg & Oegema 1995), Austria (Stockhammer et al. 1995), British Columbia (Gustavson & Lonergan 1994), Sweden (Jackson & Stymne 1996) and Chile (Castaneda 1999). For this study, I calculated the Finnish ISEW and applied it on the basis of Daly and Cobb's proposition. The progresses of the Finnish Gross National Product (GNP) and Index of Sustainable Economic Development (ISEW) at real prices are depicted in Figure 20 and, in more detail, in Statistical Appendix 9.

As can be seen from Figure 20, sustainable economic welfare rose steadily in the 1970s and early 1980s, but has since declined and stabilised. According to Castaneda (1999, 237), in other countries where the ISEW has been adopted, it also runs parallel to the GNP at lower rate of change until the 1970s, whereafter a faster decline is observed. The Netherlands forms

Figure 20.
Progress of GNP and ISEW per capita in Finland in 1960–2000 (FIM 1,000, rp)



the only exception. In the case of Finland the main reason for this development was effective income distribution which apportioned evenly the welfare derived from increased production. In the mid-1980s income disparities started to grow again, flows of capital (investments) abroad increased and environmental hazards escalated, resulting in a decline in the weighted personal consumption on which the Finnish ISEW is actually based. In order to obtain the ISEW, unpaid household work, together with services obtained from durables, and public services, are added to the weighted personal consumption and several environmental deterioration and wasteful activities are subtracted from it. Table 4 illustrates the major components of the Finnish ISEW. These components, with the sources of their numerical values, are also presented in more detail in Appendix 10.

Table 4.
Major contributors to Finnish ISEW in 2000 (FIM billion, rp)

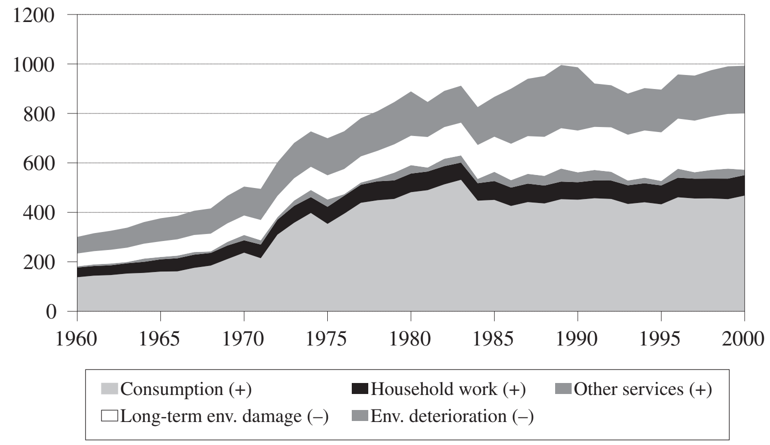
Weighted personal consumption	467.8
Household work	82.8
Other positive contributions	21.7
Long-term environmental damage	–228.0
Environmental deterioration	–192,5
ISEW	**151,8**

Source: MoE (1991), 127.

In Table 4 the "Weighted personal consumption" concept of the ISEW forms some 47 per cent of the total sum of positive and negative contributors' values (FIM 992.8 billion), while household work accounts for 8.3 per cent and long-term environmental damage for 23 per cent. The term "Other positive contributions", with its 2.2 per cent share, includes durable consumer goods, streets and highways, private expenditure on health and education, net capital growth, and change in international position. Environmental deterioration consists of national advertising expenditure, costs of commuting, urbanisation, car accidents, water, air and noise pollution, loss of wetlands and farmlands, and depletion of non-renewable resources. Its total share is 19.5 per cent. Figure 21 gives a further illustration of the development of the values of these positive and negative components from 1960 to 2000.

Figure 21 confirms the view that throughout history the basis of the Finnish ISEW has been the weighted personal consumption of individuals, which reached its peak of some FIM 531 billion at real prices in 1983. Since then the weighted personal consumption declined and later stabilised to around FIM 450 billion at real prices. The other major positive component of the ISEW, i.e. household work, has also grown somewhat in size over the years. The negative components of the ISEW, the so called environmental deterioration and long-term environmental damage, that approximate the cumulative environmental damage caused by economy, have also grown strongly. However, in the 1990s the value of environmental deterioration has decreased thanks to the efficient environmental protection activities.

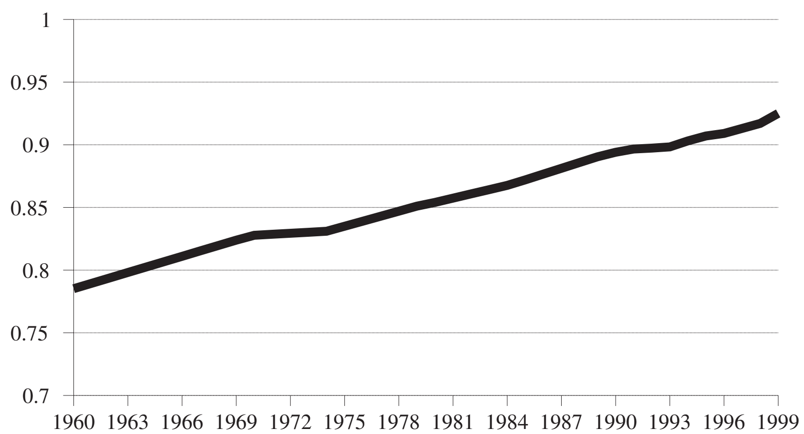
Figure 21.
Progress of the components of Finnish ISEW (FIM billion, rp)



Finally, as a general observation it can concluded that, as such, the ISEW measure is a remarkably stable aggregate indicator. Beside fluctuations in the "weighted personal consumption" component the ISEW is not so sensitive to any fluctuations in the numerical values of one or two of its variables.

Besides the ISEW, the Human Development Index (HDI) developed by the United Nations Environmental Programme (UNDP) can also be utilised in depicting the progress of welfare in Finland from another angle. According to the UNDP's comparisons of the HDI and GDP per capita rankings between countries, the disparity among countries is much greater in income (GDP per capita) than in human development (HDI). Thus, there seems to exist no link between the level of per capita income in a country and the level of its human development. (UNDP 1990, 15) The HDI's major components are life expectancy at birth, adult literacy rate, combined enrolment ratio and income adjusted per capita expressed as PPP (= Purchasing Power Parity) or distribution-adjusted GDP per capita in US dollars. Thus the HDI is intended to measure average achievements in the basic dimensions of human development. The HDI is as such intended to depict the potentials of the developing countries to develop in the future. (UNDP 1999, 127) However, the UNDP has also applied the HDI to industrialised countries, including Finland. The Finnish Human Development Index in 1960–1999 is depicted in Figure 22 and in Statistical Appendix 9.

Figure 22.
Progress of Finnish Human Development Index



Sources: UNDP 2001, 145; UNDP 2000, 178; UNDP 1999, 1998 and 1990.

As can be seen from Figure 22, the HDI indicator follows a somewhat similar trend to that of the ISEW index. (See Figure 21) However, since the ISEW emphasises economic factors and the HDI social ones, the HDI ignores totally the upward turn of economic welfare of the 1970s, and the recession of the early 1990s which passed without decline in the overall level of components of welfare measured in HDI but was financed with loans that reduced the economic welfare measured by the GDP and ISEW.

These are the various indicators of sustainable development that can be utilised. However, they all have their limitations. The conventional Gross Domestic Product (GDP) measures the economic output of an economy and thus says nothing about the sustainability of the development and, furthermore, is not a measure of welfare. Its derivative, the Environmentally adjusted Domestic Product (EDP) also measures the economic output of an economy but it also subtracts the depreciation of capital and environmental effects from the actual output. However, this measure is highly dominated by economic output. Consequently, it reflects the current level of economic activities and fails to picture the actual welfare reached in a society. The Direct Material Flow (DMF) and Total Material Flow (TMF) indicators, on the other hand, neglect all social and economic aspects of sustainable development. The alternative socio-political indicators of the Human Development Index (HDI) and the Index of Sustainable Economic Welfare (ISEW) give a better picture of people's actual welfare. Their major drawback from the perspective of sustainable development is that they fail to take the environment sufficiently into account. Table 5 presents the annual changes of the GDP, GNP, EDP1, EDP2, ISEW and HDI through the 1960s to the 1990s.

Table 5 shows that the fastest annual growth rates in the real GDP, 4.05 per cent, and in the Human Development Index, 0.54 per cent, were achieved during the 1960s. The ISEW also grew by 4.70 per cent, although

Table 5.
Annual changes of certain welfare indicators in Finland by decades (per cent)

	During 1960s	During 1970s	During 1980s	During 1990s
GDP	+ 4.05	+ 3.13	+ 3.02	+ 1.49
GNP	+ 3.96	+ 3.07	+ 2.93	+ 1.61
EDP1	+ 4.05	+ 2.59	+ 2.84	+ 1.81
EDP2	+ 4.00	+ 2.63	+ 3.03	+ 1.88
ISEW	+ 4.70	+ 14.69	– 5.18	+ 3.66
HDI	+ 0.54	+ 0.31	+ 0.46	+ 0.32

its largest annual increase of 14.69 per cent occurred in the 1970s. In the 1970s the GDP grew by 3.13 per cent annually. In the 1980s the direction of the development turned, as the ISEW declined by 5.18 per cent and the HDI somewhat stabilised with a 0.46 per cent annual growth. However, at the same time the GDP grew annually by 3.02 per cent. In other words, the growth in production did not increase the welfare of the people. However, from 1990 to 1999 all these indicators imply a turn towards more positive development. Especially the ISEW has grown considerably more, i.e. by 3.66 per cent, than the GDP, i.e. 1.49 per cent. The HDI also implies more positive development than in the 1970s and 1980s. As the SNA-based components of some of these indicators (namely GDP, GNP, EDP1 and EDP2) are quite sensitive to economic fluctuations it is important to examine longer term trends in them. This is done in Table 6.

Table 6 shows that in the period 1975–2000 the Sustainable Economic Welfare of Finns stabilised with annual growth of only 0.06 per cent, although at the same time the GDP grew by 2.27 per cent. During the 1985–2000 period the development was even more negative as the economic welfare declined by 1.77 per cent at the same time as the GDP increased by 2.26 per cent. It can be concluded that the distribution of the wealth generated did not benefit the majority of the people during the 1980s and 1990s. An ever increasing share of the value added produced by the economy was apportioned to income on capital instead of salaries. Consequently, for the majority of people the economic welfare obtained through wages has not improved, and the wealth generated is directed increasingly to capital owners instead. On the other hand, the annual growth rates of the HDI of 0.39 per cent during 1975–2000 and 0.42 during 1985–2000 imply that the well-being of the people was fostered through improvements in

Table 6.
Annual changes of certain welfare indicators in Finland by certain periods (per cent)

	During 1960–2000	During 1975–2000	During 1985–2000
GDP	+ 3.08	+ 2.26	+ 2.26
GNP	+ 3.09	+ 2.26	+ 2.30
EDP1	+ 2.95	+ 2.21	+ 2.31
EDP2	+ 3.02	+ 2.30	+2.40
ISEW	+ 4.87	+ 0.08	– 1.77
HDI *)	+ 0.41	+ 0.39	+ 0.42

*) = data until 1999.

public services, such as better level of education and improved health and other social services. However, this redistribution of social income improved mainly the situation of certain social groups, like the poor, unemployed, sick, etc., and made the middle class that gets its support from salaries pay the bill.

5.4 A review of the eco-efficiency of the Finnish economy

Materials accounting provides many new insights into the physical basis of a particular society. Eco-efficiency research aims at integrating all three dimensions of sustainable development, i.e. economic, environmental and social, together in a totally new way. The benefits of this approach are numerous. However, before proceeding to the actual analysis, it is crucial to keep in mind the uncertainties and problems that relate to the practical application of these methods. From the biological viewpoint, the use of a small amount of some highly toxic substance in the economy may have a greater impact than the use of a much larger amount of relatively harmless stone. As a result, the summation of various material tonnages into a single measure provides a very rough picture of the state of the environment and it can easily be accused of being irrelevant because different materials have different environmental problems. For example, many environmental scientists feel uncomfortable about summing up the masses of different materials. There is no universally accepted weighting system, however, for evaluating the environmental effects of different materials. Hence, this simplifying hypothesis allows making macro-scale analyses and international comparisons on materials use. Keeping the shortcomings in mind, we can compile and use aggregated materials measures to estimate changes in the use of materials. These estimates are the most reliable ones for analysing in detail the materials use of an economy.

In Chapter 2, I presented the various methods of measurement with which the trend of the overall eco-efficiency can be viewed at the level of the whole society. In this study, the conventional Gross Domestic Product (GDP) its derivative, the Environmentally adjusted Domestic Product (EDP1), the Human Development Index (HDI), the Index of Sustainable Economic Welfare (ISEW) and the Direct Material Flow (DMF) are mainly used in the empirical analysis. In this Section I use the conventional Gross Domestic Product (GDP) per Direct Material Flow (DMF) ratios in an empirical analysis to estimate the eco-efficiencies of certain industrialised economies. As a highly aggregated and rough background indicator, the DMF is comparable to the GDP in economic terms. (See e.g. Huttler et al. 1997) The overall picture of the materials use of an economy will be confused by the inclusion of unused resources (hidden flows) in an aggregate indicator (like the TMR). The TMR measure is considered to be quite problematic, since its insensitivity to the size of external trade is considered to reduce its informative value. When the TMRs of two countries are compared, trade between them is included under output in the country of export and under imports in the country of import despite the fact that the resources involved are used only once. (Danish Ministry of Finance 2001, 12) I exclude the Total Material Flow (TMF) indicator from this study since my main focus is on an analysis of economic welfare. I have studied the eco-efficiency of the Finnish economy by using the following Eco-efficiency 1–4 (or EE1, EE2, EE3 and EE4) formulas (5.4.1), (5.4.2), (5.4.3) and (5.4.4). (For further details see formula (4.1.2) and Adriaanse et al. 1997, 14):

$$\text{(5.4.1)} \quad \text{Eco - efficiency 1} = \frac{\text{GDP}}{\text{DMF}}$$

$$\text{(5.4.2)} \quad \text{Eco - efficiency 2} = \frac{\text{EDP1}}{\text{DMF}}$$

$$\text{(5.4.3)} \quad \text{Eco - efficiency 3} = \frac{\text{ISEW}}{\text{DMF}}$$

$$\text{(5.4.4)} \quad \text{Eco - efficiency 4} = \frac{\text{HDI}}{\text{DMF}}$$

The results obtained using formulas (5.4.1), (5.4.2), (5.4.3) and (5.4.4) are presented in Figures 23 and 24 and in Statistical Appendix 11.

As Figure 23 shows, the total eco-efficiency of the Finnish economy has clearly improved since early 1970s as viewed through the GDP/DMF and EDP1/DMF measures. Compared to 1960, Eco-efficiency 1 had improved by a total of 77.4 per cent and Eco-efficiency 2 by 69.5 per cent by 2000. The most rapid improvement took place in the mid-1970s and since then the average trend has been rising slightly upwards. Figure 24 presents the trends of Eco-efficiency 3 (ISEW/DMF ratio) and Eco-efficiency 4 (HDI/DMF ratio). Compared to 1960, Eco-efficiency 3 had improved by a total of 7.0 per cent by 2000 and Eco-efficiency 4 decreased by 34.4 per cent by 1998. The overall trend in both cases is a downward one, which indicates a somewhat declining development.

Figure 23.
Overall Eco-efficiencies 1 and 2 of the economy in Finland

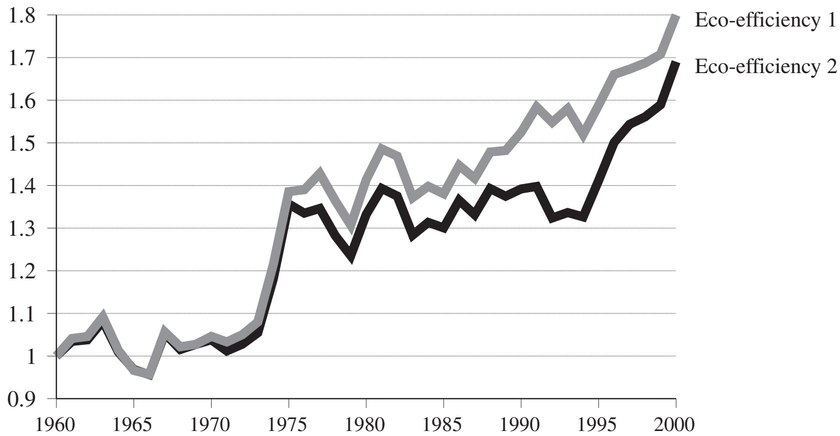
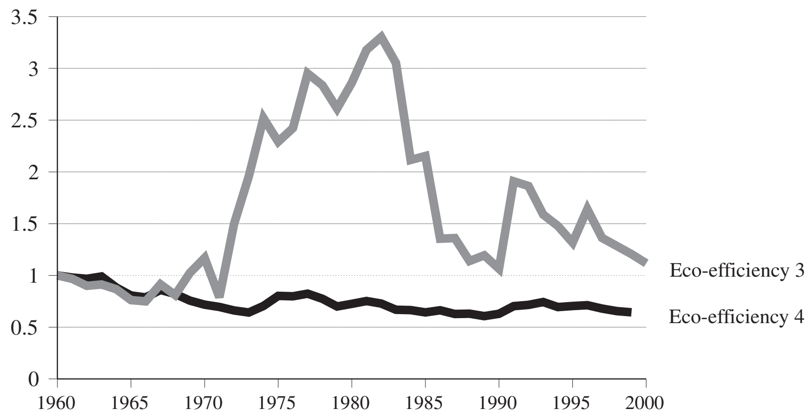


Figure 24.
Overall Eco-efficiencies 3 and 4 of the economy in Finland



The annual changes of Eco-efficiency 1 (GDP/DMF ratio), Eco-efficiency 2 (EDP1/DMF ratio), Eco-efficiency 3 (ISEW/DMF ratio) and Eco-efficiency 4 (HDI/DMF ratio) through the 1960s to the 1990s are presented in Table 7.

Table 7.
Annual changes of Eco-efficiencies 1–4 in Finland by decades (per cent)

	During 1960s	During 1970s	During 1980s	During 1990s
Eco-efficiency 1	+ 0.43	+ 2.42	+ 0.53	+ 1.46
Eco-efficiency 2	+ 0.41	+ 1.94	+ 0.38	+ 1.51
Eco-efficiency 3	+ 1.06	+ 12.33	– 6.96	+ 2.93
Eco-efficiency 4	– 2.88	– 0.02	– 1.71	+ 1.57

It can be seen from Table 7 that Eco-efficiency 1 (GDP/DMF ratio) and Eco-efficiency 2 (EDP1/DMF ratio) show a positive trend, i.e. less materials are used through the 1960s to the 1990s per value added in production. However, Eco-efficiency 3 (ISEW/DMF ratio) and Eco-efficiency 4 (HDI/DMF ratio) give a slightly different impression of the development, implying that especially during the 1980s, the development was not eco-efficient, but "eco-inefficient". The values of the indicators in Table 7 differ quite a lot from each other between the different periods. Therefore, I also examined longer periods. The values of Eco-efficiencies 1–4 for the periods 1960–2000, 1975–2000 and 1985–2000 are presented in Table 8.

Table 8 shows that during the period 1960–2000 Eco-efficiencies 1–3 showed a positive trend. The ISEW-based Eco-efficiency 3 indicator developed particularly positively, with an average of 2.73 per cent increase over this 40-year period. However, in shorter periods starting from 1975 and 1985, Eco-efficiency 3 shows negative, or inefficient, development and the closer we come to the present day the more inefficient is the development according to this indicator, whereas the GDP, EDP1 and HDI- based Eco-efficiencies 1, 2 and 4 turn into a positive direction. It is only during the mid and late 1990s that the ISEW-based Eco-efficiency 3 shows again a positive, or eco-efficient, development taking place.

Table 8.
Annual changes of Eco-efficiencies 1–4 in Finland by certain periods (per cent)

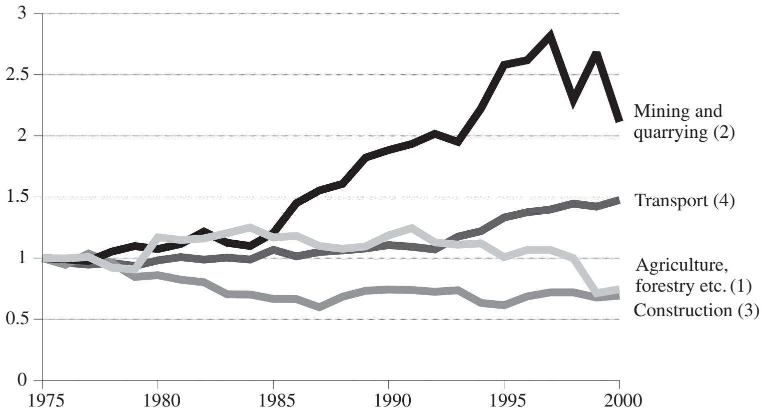
	During 1960–2000	During 1975–2000	During 1985–2000
Eco-efficiency 1	+ 1.58	+ 1.12	+ 1.82
Eco-efficiency 2	+ 1.43	+ 0.96	+ 1.82
Eco-efficiency 3	+ 2.72	– 0.90	– 1.75
Eco-efficiency 4	– 0.96	– 0.80	+ 0.11

In principle it is also possible to review the eco-efficiencies of the individual sectors of the economy. However, unavailability of data forms a major constraint to such an analysis. Especially data on materials use are extremely difficult to allocate to certain sectors, since materials circulate from one sector to another within the economy. However, it is possible to calculate some general estimates about the eco-efficiencies of certain sectors, mainly those of primary production. At the sector level, the value added at real prices, derived directly from National Accounts, is the only available indicator of the economic benefits received by an individual sector each year. Keeping in mind these points, certain sectoral eco-efficiencies of the Finnish economy can now be studied using the following Eco-efficiency 5 (or EE5) formula (5.4.5). (For further details see Adriaanse et al. 1997, 14):

$$(5.4.5) \quad \text{Eco} - \text{efficiency } 5 = \frac{\text{VA}}{\text{DMU}} ,$$

where *VA* is the value added of that particular sector and *DMU* corresponds with the direct primary materials use. The results obtained are presented in Statistical Appendix 11 and in Figure 25, which depicts the estimated eco-efficiencies of certain primary production sectors of the Finnish economy, namely (1) Agriculture, hunting, forestry and fishing, (2) Mining and quarrying, (3) Construction and (4) Transport.

Figure 25.
Eco-efficiencies of certain primary production sectors of Finnish economy

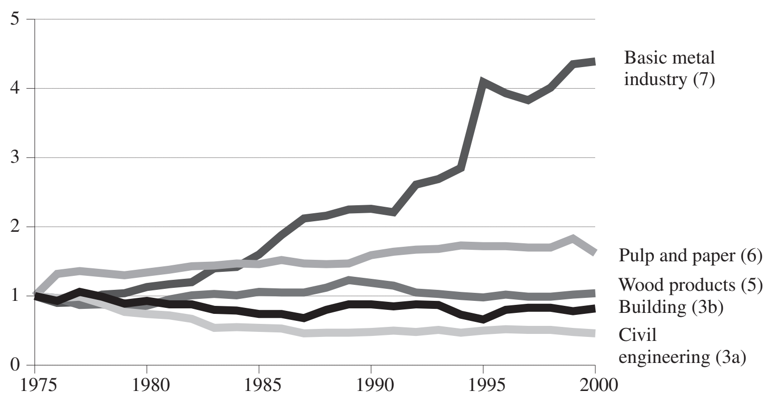


As can be seen from Figure 25, the eco-efficiency of mining and quarrying (2) improved greatly during the late 1980s and in the early 1990s whereas the eco-efficiency of construction (3) declined. In the late 1990s the eco-efficiency of transport (4) has improved while the eco-efficiencies of agriculture, hunting, forestry and fishing (1) and of mining and quarrying (2) has declined a bit.

Although unavailability of data severely restricts analyses of the eco-efficiencies of different industrial sectors, some general estimations about the eco-efficiencies of certain secondary production sectors can be calculated bearing in mind the dilemmas presented above. I have also used formula (5.4.5) to estimate the eco-efficiencies of certain industries in Finland, namely (3a) Civil engineering (or land and water construction), (3b) Building of complete constructions or parts thereof, as well as those of some secondary sectors like (5) Manufacture of wood and wood products, (6) Manufacture of pulp, paper and paper products, and (7) Manufacture of basic metals. The results obtained are presented in Figure 26 and in Appendix 11.

As can be seen from Figure 26, the eco-efficiency of the basic metal industry (7) improved significantly during the late 1980s and in the 1990s. The eco-efficiency of the pulp and paper industry (6) has also almost doubled during this 26-year period. The eco-efficiency of the wood products industry (5) has remained quite stable over the years, but the eco-efficiencies of civil engineering (3a) and manufacture of complete constructions, etc., (3b) have declined during the same period.

Figure 26.
Eco-efficiencies of certain industrial sectors of Finnish economy



In conclusion it can be stated that, the eco-efficiencies of mining and quarrying and basic metal industry have improved most, and there are also positive signs of improving eco-efficiency in pulp and paper and wood products sectors. There sectors are also the most material intensive sectors in Finland. In other sectors the eco-efficiencies have been quite stabile or even declining. It should be borne in mind that the eco-efficiencies presented here are estimates and that the coverage and accuracy of the data could be better. Nevertheless, these figures do help to identify certain problems relative to the use of natural resources in Finland, namely the seemingly inefficient processing of raw materials if compared to the economic parameters.

5.5 Trends in the eco-efficiencies of certain industrial economies

In this Section I use different welfare indicators per Direct Material Flow (DMF) in an empirical analysis to estimate the eco-efficiencies of certain industrialised economies. At first I study the eco-efficiencies of these economies by using the Eco-efficiency 1 formula (5.4.1), which represents the very traditional and commonly used form of eco-efficiency perspective and serves as a starting point to my research. I review the data on Finland, Germany, the Netherlands, Austria and Japan through this formula. The utilised material flow data on Germany, the Netherlands, Austria and Japan were compiled by Matthews et al. (2000, 58–59, 72–73, 84–85, 98–99) and those on Finland by myself for this study. (See Appendix 5) The results obtained using formula (5.2.1) are presented in Figure 27 and in Statistical Appendix 12.

According to Figure 27, Eco-efficiency 1 of all of these economies improved during the reviewed period. Compared to 1975, Eco-efficiency 1 improved by a total of some 65 per cent in Japan but only by some 30 per cent in Austria and Finland by 1996. For Germany the corresponding figure was some 46 per cent and for the Netherlands 38 per cent. Among these countries Finland is relatively small in terms of population size and thus it would be most interesting to compare the Finnish economy to a similar Nordic society. The available material flow data for Sweden only cover years 1987 to 1998 (Jonsson et al. 2000, bilaga 5) and therefore the analysis must be restricted to this period. The progress of Eco-efficiency 1 in Finland and Sweden between 1987 and 1998, obtained using formula (5.4.1), are presented in Figure 28 and in Statistical Appendix 12.

Figure 27.
Progress of Eco-efficiency 1 in certain industrialised countries in 1975–1996

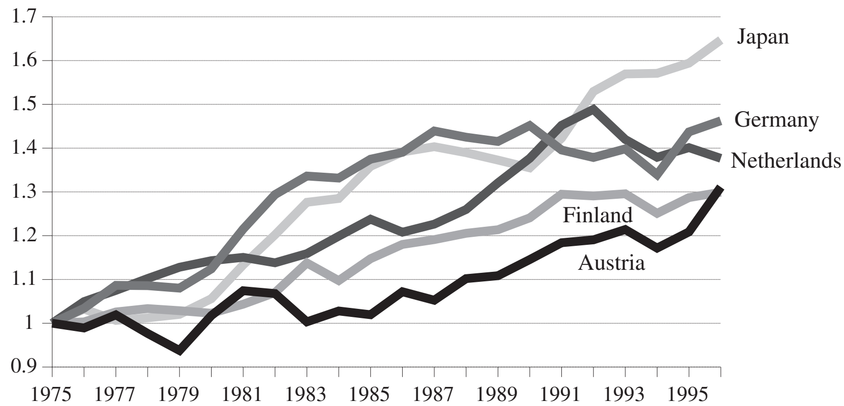
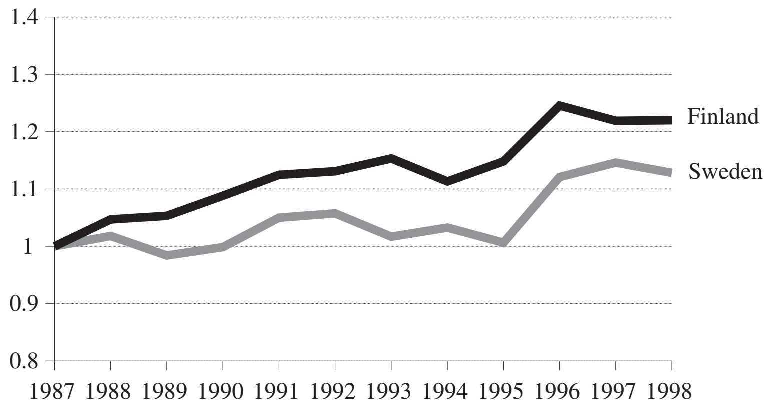


Figure 28.
Progress of Eco-efficiency 1 in Finland and Sweden 1987–1998



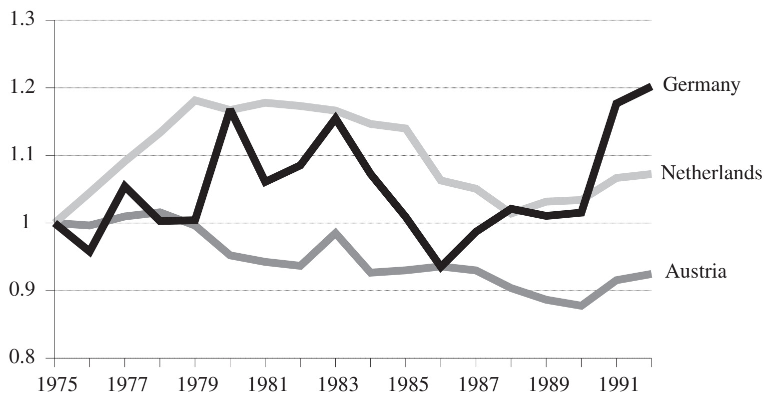
In Figure 28 the Finnish and Swedish Eco-efficiencies 1 follow each other surprisingly well and accurately, although the Finnish one apparently improved somewhat and remained some 7 per cent higher than the Swedish one in 1998. The GDP/DMF ratio gives one proxy of the progress of eco-efficiency at the national economy level. The main weakness of this formula is that the GDP is no measure of "improvement of quality of life" or "value added". Thus better "quality of life" indicators should be utilised in an eco-efficiency analysis.

I am unable to deepen the analysis because no EDP calculations are available for these countries. However, several ISEW time series have been drawn and thus it is possible to compile Eco-efficiency 3 measures for Germany, the Netherlands and Austria. The progress of the Eco-efficiency 3 measures of these countries, obtained using formula (5.4.3), between 1975 and 1992 are presented in Figure 29 and in Statistical Appendix 12.

According to Figure 29, Eco-efficiency 3 of Germany and the Netherlands improved during the period reviewed, but that of Austria declined. Compared to 1975, Eco-efficiency 3 had improved by a total of 20.2 per cent in Germany and by 7.2 per cent in the Netherlands but decreased by 7.5 per cent in Austria. The reasons for this development are interesting to note. In Germany, both the ISEW and the DMF grew. It seems that the DMF follows the growth pattern of the ISEW with some delay. In the Netherlands the ISEW and the DMF both remained quite stable over the reviewed period, although the ISEW grew a little. In Austria the ISEW remained quite stable at the same time as the DMF continued to grow.

Data are available for these countries on the HDI, a better "quality of life" indicator, which can now be adopted into this eco-efficiency analysis. Consequently, I studied the eco-efficiencies of the industrial economies using the Eco-efficiency 4 formula (5.4.4), i.e. the HDI per DMF measure. Equation (5.4.4) represents a novel approach to eco-efficiency analysis; I

Figure 29.
Progress of Eco-efficiency 3 in Germany, Netherlands and Austria 1975–1992



used it as a starting point for the following analysis. I analysed the data on Finland, Germany, the Netherlands, Austria and Japan using this formula. The utilised material flow data on Germany, the Netherlands, Austria, Japan were compiled by Matthews et al. (2000, 58–59, 72–73, 84–85, 98–99) and those on Finland by myself. (See Appendix 5). The Human Development Index (HDI) data for 1975–1996 were compiled by the UNDP (2000, 178). The results obtained using formula (5.4.4) are presented in Figure 30 and in Statistical Appendix 12.

According to Figure 30, Eco-efficiency 4 of all of these economies decreased during the period reviewed. Compared to 1975, Eco-efficiency 4 decreased by a total of 18.6 per cent in Germany, 16.3 per cent in Austria and 13.7 per cent in Japan, but only by 8.9 per cent in Finland and 8.7 per cent in the Netherlands by 1996. In the case of Germany, we must bear in mind that the German reunification that occurred in October 1989 affected greatly the situation of Germany. Before 1989 Germany was progressing along eco-efficient lines and achieved 25 per cent improvement in eco-efficiency by 1987 compared to 1975. However, the reunification changed the situation totally and since the late 1980s the German eco-efficiency has declined by almost 40 per cent.

Since the available material flow data for Sweden only cover the years 1987 to 1998 (Jonsson et al. 2000, bilaga 5), its Eco-efficiency 4 analysis is restricted to this period. I present the changes in Eco-efficiency 4 in Finland and Sweden between 1987 and 1998, obtained using formula (5.4.4), in Figure 31 and in Statistical Appendix 12.

Figure 30.
Progress of Eco-efficiency 4 in certain industrialised countries in 1975–1996

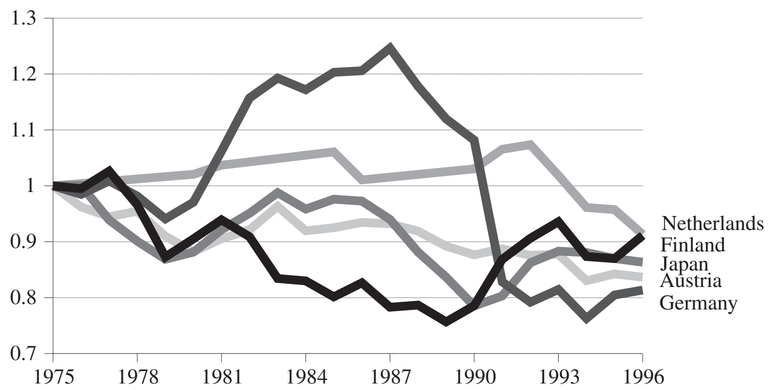
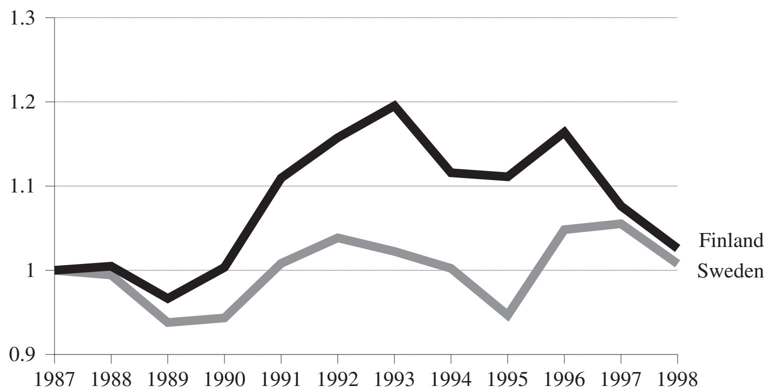


Figure 31.
Progress of Eco-efficiency 4 in Finland and Sweden 1987–1998

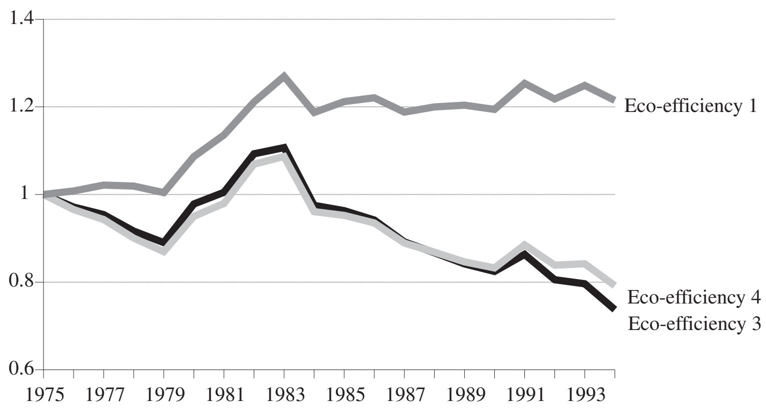


The Finnish and Swedish Eco-efficiency 4 measures seem to follow each others quite well, although the Finnish one apparently improved a little more and remained 4.7 per cent higher than the Swedish one in 1998. However, during the middle of the reviewed period these eco-efficiencies of Finland and Sweden separated from each other. Whereas the Finnish Eco-efficiency 4 measure started to improve in 1989 and reached a peak of 19.5 per cent improvement in 1993 compared to 1987, the Swedish measure turned upwards only in 1990 reaching its peak of 3.9 per cent improvement in 1992. The trends of the Finnish and Swedish Eco-efficiency 4 measures remained at their own levels and it was only in 1996 that their paths approached each others again.

There is also enough data to draw up Eco-efficiencies 1, 3 and 4 for the United States for the period of 1975 to 1994 by using formulas (5.4.1), (5.4.3) and (5.4.4). However, in formula (5.4.3) the ISEW -measure must be replaced by the GPI measure in order to extend the analysis up to 1994. The progress of Eco-efficiencies 1, 3 and 4 in the USA between 1975 and 1994 is presented in Figure 32 and in Statistical Appendix 12.

As can be seen from Figure 32, none of the eco-efficiency indicators of the USA indicate positive progress during recent years. The Eco-efficiency 1 measure has remained stable since 1984 and Eco-efficiencies 3 and 4 have also declined since 1983. In 1994, Eco-efficiency 1 was still some 21.5 per cent above the 1975 level thanks to the positive developments during the late 1970s and early 1980s. However, Eco-efficiency 3 has decreased by some 20.8 per cent and Eco-efficiency 4 by some 26.3 per cent since 1975.

Figure 32.
Progress of Eco-efficiencies 1, 3 and 4 in the United States 1975–1994



The Eco-efficiency 1, 2, 3 and 4 measures give an interesting proxy of the progress of eco-efficiency at the national economy level. The main weaknesses of these formulas are problems in measuring the welfare generated in the economic processes. The use of the GDP as a proxy for welfare overvalues the benefits of economic production. The main weakness of the HDI as a measure of welfare is that it counts developments that have already long ago occurred in industrialised countries because it is a measure intended for developing countries. Thus the measure of Eco-efficiency 4 is dominated by variations in the DMF aggregate and the progress of the Eco-efficiency 2 measure seems to be almost non-existent in the industrialised countries. The ISEW and GPI measures utilised in the Eco-efficiency 3 measure seem in these respects to be the most suitable measures of welfare for eco-efficiency analyses at the national economy level. However, they also have their own limitations, the main problem being the inclusion of distribution of income in the aggregated calculations. Thus better “quality of life” indicators should be utilised in the eco-efficiency analyses of industrialised economies. I address the question of adequate measurement of welfare in the next Chapter.

6 Developing further Finnish eco-efficiency measures

6.1 Towards a more adequate measurement of overall welfare

A major challenge of this study now is to define the well-being of a society in a way that enables the construction of an indicator of the true well-being in both the society and in the surrounding environment. I address this challenge in this Chapter. Generally, the economics of welfare, a subsection of the neoclassical economic theory, clearly state that human beings not only receive well-being from the commodities produced in an economy but also from the material and immaterial commodities and services available direct from nature. In welfare economics, these free and non-market commodities and services also contribute to the overall welfare stock of society. However, the neoclassical assumption that individuals make optimal choices within their budget constraints clearly excludes the non-market priced commodities and services from the optimal stock of welfare desired by individuals. The ecological economics perspective recognises this shortcoming of the neoclassical analysis, but is unable to provide new practical solutions to the problem. From the point of view of sustainable development of this welfare stock the corresponding indicators should include environmental, social and economic dimensions. In ecological economics, welfare is also regarded as a constant flow of income from the stocks of man-made capital, human capital and natural capital. The weighting of these dimensions or flows from each particular capital stock on the basis of their actual contribution to the overall flow of welfare received by individuals is, however, a major obstacle in the creation of an indicator of overall welfare.

The actual trends of the Finnish eco-efficiencies – or, more accurately, those of the welfare indicators presented in Chapter 5 – were quite different. As a rule, during the late 1980s and 1990s, rapid growth of the GDP and EDP was sharply contrasted by a decline and stabilisation of the ISEW. On the other hand, the almost constant trend of the HDI implies that no major changes have occurred over the past decades in the level of well-being received by people. Moreover, there seems to be no link whatsoever between the GDP, ISEW and HDI. Comparison of the welfare indicators with the DMF reveals that no correlation can be found in the trends of the ISEW and DMF. However, there appears to be a positively correlated link between the DMF and GDP, which are both measures focused toward describing the production processes of an economy. These observations are significant as they imply that, after the mid-1980s, the ever increasing wealth generated by the society has not benefited the common people, on average, but that their level of welfare or quality of life has actually decreased. The distribution of available welfare has, in fact, been inefficient if we consider that the goal of an economy is to distribute the wealth created by economic processes effectively back to the people. By and large, on the basis of these observations we can conclude that the materials use, or the DMF, of a society does not bring about a direct increase in the level of welfare or in the quality of life. The choices made through political, democratic processes concerning the distribution of the generated welfare seem to affect the overall eco-efficiency of society so greatly that, depending on the choice of the welfare indicator, eco-efficiency analysis easily turns from an analysis of the efficiency of production processes and techniques to criticism of the practised policies. Is this the task of an eco-efficiency analysis? The answer can be both yes and no. From the point of ecological economics, the efficiency of a political process is not an essential question as such, but from the environmental and social policy perspective it is a crucial one. However, if inefficient political processes subsequently increase the materials use, or the DMF, of an economy while individuals accelerate their activities towards achieving economic prosperity, this also becomes an economics question. If inefficient political decisions can be shown to cause unnecessary increase in DMF, we have identified a major reason for inefficiency in welfare in the society.

The main finding in Chapters 5 was that different welfare indicators give different pictures of the development of overall welfare in society. This problem also influences the eco-efficiency results obtained from the analysis. A particular problem observed in Chapter 5 was that these aggregate indicators, like the GDP, ISEW and HDI, can all point to different directions at the same time depending on the progress and direction of the welfare dimension they represent. The GDP measures the level of production excluding the external effects of production, the ISEW emphasises the economic possibilities of individuals and the HDI appreciates the factors of well-being that tell about the long-range future possibilities for economic development. In the light of the history of Finland, the ISEW appears to be the best indicator of welfare, as the GDP measures the level of production that does not in most cases contribute to the welfare of the people and the HDI, which emphasises such public factors of development as education and health services, is clearly more suitable for developing countries. However, in the case of Finland the ISEW fails to follow the growth of the human capital and its future potential. The “investments” made today in education, health and other social services – of which there are plenty in Finland – contribute to welfare in the future This inability to identify future potential is one major weakness of the ISEW in the case of Finland. The environment perspective is best observed by the ISEW. The EDP1 derivative of the GDP fails to emphasise the environmental hazards adequately because of the problem of pricing. However, the GDP and EDP measures have as their starting point the premise that economic welfare originally comes from production. The ISEW and HDI indicators are, in fact, reflect political decisions about how produced assets are re-allocated in society.

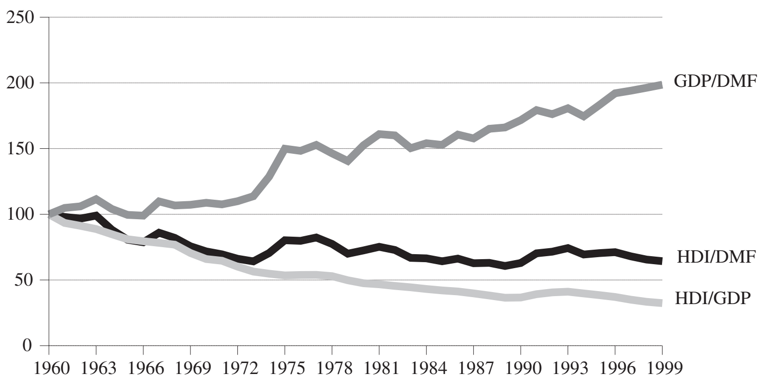
This problemacy between economic gains generated from material flows, and welfare generated from these economic gains, can also be decomposed by using the following formula (6.1.1):

$$(6.1.1) \qquad \frac{GDP}{DMF} \times \frac{HDI}{GDP} = \frac{HDI}{DMF}$$

In equation (6.1.1) the first ratio, GDP/DMF, describes the economic gains generated from material flows and the second ratio, DMF/HDI, the welfare actually generated from economic gains. Figure 33 and Statistical Appendix 13 present the progress of these ratios, calculated on the basis of formula (6.1.1), in Finland during the 1960–1998 period.

Figure 33 depicts clearly that the conversion rate for economic gains generated from materials into welfare has been progressing in an inefficient

Figure 33.
Development of materials conversion to welfare in Finland in 1960–1999 (1960=100)



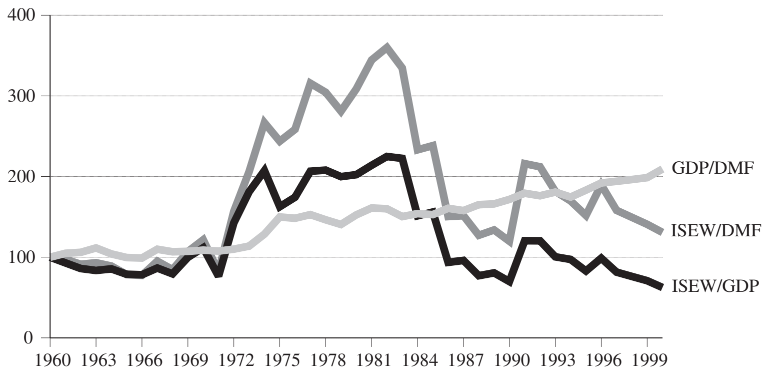
direction. A similar analysis can also be made using the ISEW instead of the HDI indicator. Thus, this problemacy can also be decomposed by using the following formula (6.1.2):

$$(6.1.2) \qquad \frac{GDP}{DMF} \times \frac{ISEW}{GDP} = \frac{ISEW}{DMF}$$

In equation (6.1.2) the first ratio, GDP/DMF, describes the economic gains generated from material flows and the second ratio, ISEW/GDP, the welfare actually generated from economic gains. Figure 34 describes the same progress as Figure 33 does, but the welfare is being measured by the ISEW indicator. (Data is also presented in Statistical Appendix 13)

Figure 34 confirms the previous finding that the conversion rate for economic gains generated from materials into welfare has been progressing in an inefficient direction during the 1990s. As a consumption-based measure the ISEW is independent from the value added generated by production in short time periods. As such, sustainable economic welfare measured by the ISEW is mainly determined by political decisions concerning income distribution. Exclusion of the fairness of income distribution policies is necessary in order to achieve meaningful results concerning the actual economic-environmental eco-efficiency. My next aim is to design an aggregate measure that evaluates the gains achieved through production activities more adequately. The aim of this new aggregate measure is to present a more reliable estimate of the progress of actual gains from economic growth and, at the

Figure 34.
Another view of the development of materials conversion to welfare in Finland in 1960–2000 (1960=100)



same time, avoid the income distribution confusion of the ISEW originating from political decisions. Thus, the new measure will focus on giving an overall picture of the wealth generated and bypass social policy problems of income distribution, taxation and social welfare subsidies.

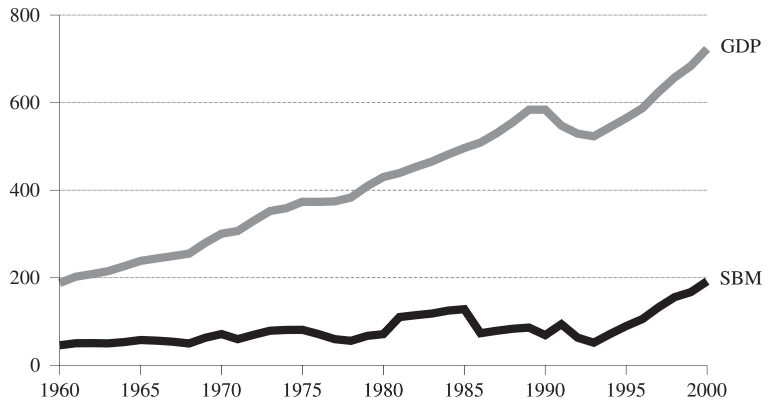
This new measure, which I have named the "Sustainable net Benefit Measure of production", or SBM for short, measures the value of the output generated by an economy or the welfare potential of a society. The distribution of the welfare generated, i.e. the "rightness" of political decisions, is thus excluded from this particular measure. The SBM takes as its starting point the conventional GDP, from which "Incomes from ROW" and "Consumption of fixed capital" are subtracted in order to arrive at the SNA's conventional Net National Income, or NNI, measure. After that, and as in the ISEW, all environmental and human life drawbacks are subtracted from the NNI in order to obtain the SBM. As a formula, the SBM can be expressed as follows:

(6.1.3) $SBM = NNI - TE - NE - NR - OE$,

where SBM is the Sustainable net Benefit Measure of production,
NNI is the Net National Income,
TE is the Total Environmental expenditure of society,
NE is the Negative side Effects of economic activities,
NR is the human-caused change in Natural Resources (in quantity and quality), and
OE is the Other human-caused changes in Ecosystems (in quantity and quality).

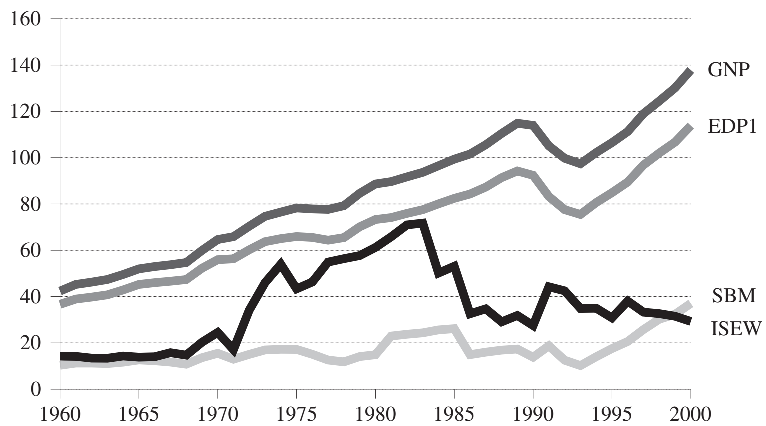
The point of departure of the SBM formula (6.1.3) is the Net National Income (NNI) concept of the SNA, from which four major negative components are subtracted. Total environmental expenditure of society (TE) includes all costs of environmental protection activities by the state, municipalities, industry and NGOs. Negative side effects of economic growth (NE) include expenditure on national advertising, and the costs of commuting, urbanisation and motoring accidents. Changes in natural resources (NR) include growth and carbon binding of forests, and acid deposition and defoliation of forests. Other changes in ecosystems (OE) include the costs of water, air and noise pollution, loss of wetlands and farmland and long-term environmental damage. As such, the SBM combines elements from both the EDP and ISEW calculation methods. Figure 35 presents the progress of the real SBM calculated on the basis of formula (6.1.3) and, in comparison, the progress of the GDP in Finland during the 1960–2000 period. The data concerning the SBM and its components are presented in Appendix 14.

Figure 35.
Development of sustainable net benefit measure of production (SBM) in Finland



As can be seen from Figure 35, the SBM, which includes all drawbacks of economic development, shows a somewhat flat trend up till 1993. After that, the benefits from economic growth start to increase strongly. Compared with the SBM, the GDP reveals very different trends. As such, Figure 35 describes the economic development of an industrial society in an extremely interesting way as it shows that the actual benefits from economic growth have remained quite constant until recently. A comparison of the GNP, ISEW, EDP1 and SBM per capita is presented in Figure 36.

Figure 36.
Trends of GNP, EDP1, ISEW and SBM per capita in Finland (FIM 1,000, rp)



On the basis of Figure 36, the trends of the ISEW and SBM per capita show no significant improvement in the level of welfare. Despite the fact that the ISEW is a consumption-based measure and the SBM a production-based measure, their trends are quite coherent apart from the 1970s and 1980s when income distribution policy temporarily significantly increased welfare as measured by the ISEW. In the late 1990s, the ISEW and SBM show again a somewhat uniform trend. The trends of the GNP and EDP1, which ignore most of the external effects of production and the negative effects of production to humans, differ almost totally from the trends of the ISEW and SBM.

6.2 Prospects of the Finnish eco-efficiency

In Chapter 5, I applied several different welfare indicators to the eco-efficiency analysis of a society. I now make the assumption that none of the above used welfare indicators is alone adequate for analysing the eco-efficiency of a society since the overall eco-efficiency of a society can assume new meanings depending on the choice of the welfare indicators utilised. Thus, the different eco-efficiency indicators introduced in Chapter 5 in fact represent various dimensions of the development of eco-efficiency. To analyse the future developments of Eco-efficiencies 1, 2, 3 and 4, I analyse their past changes in the following Sections. I use the scenario technique in analysing how their forecast trends comply with environmental policy objectives, namely the Factor 4 and 10 targets.

From the environmental policy point of view, at least in industrialised countries, the very essence of eco-efficiency thinking is to achieve a reduction in the use of materials and the welfare aspect only comes second to it. The welfare of a society is actually created from materials, and thus the materials use is also taken into the analysis on the input side of the eco-efficiency ratios. Therefore, the future progress of the Finnish DMF is of great interest. In Section 5.4, the materials use of society was reviewed using the DMF indicator, though the TMF could also have been utilised. I have used the DMF to represent the total environmental burden of the economy. The use of a suitable aggregated materials measure, whether DMF or TMF, also essentially coincides with the aims set for the reduction of carbon dioxide (CO_2) emissions in order to prevent global climate change. The Factor targets common to both materials use and greenhouse gas emissions set quantitative aims for environmental policy and make these measures comparable. For the purpose of these comparisons, changes in the DMF, TMF and carbon dioxide (CO_2) emissions during the period 1960 to 2000 are presented in Table 9.

Table 9.
Annual increases of environmental indicators in Finland during certain periods (per cent)

	During 1960s	During 1970s	During 1980s	During 1990s	During 1960–2000	During 1975–2000	During 1985–2000
DMF	+ 4.02	+ 0.80	+ 2.34	+ 0.26	+ 1.68	+ 1.31	+ 0.39
TMF	+ 3.41	+ 1.60	+ 1.81	+ 0.81	+ 1.80	+ 1.74	+ 0.98
CO_2	+ 10.81	+ 3.56	– 0.19	+ 0.75	+ 3.51	+ 1.11	+ 0.69

As Table 9 shows, the average annual increase of the Direct Material Flow (DMF) was most extensive during the 1960s and 1980s. Both carbon dioxide (CO_2) emissions and Total Material Flow (TMF) also increased considerably during the 1960s and 1970s. However, the 1990s marked a clear turning point in this development. The average annual increases in CO_2 emissions, DMF and TMF were quite modest. The changes become even more apparent when the developments of the DMF, TMF and CO_2 emissions are analysed as per capita indicators, as shown in Table 10.

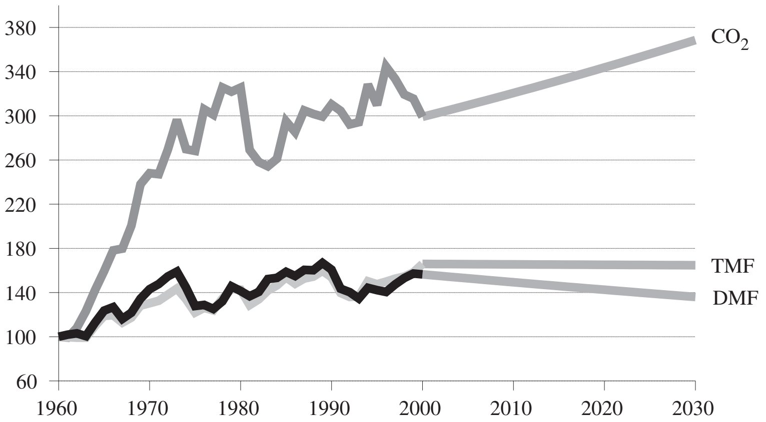
As can be seen from Table 10, the period from 1990 to 1999 shows a clear turning point as the average annual changes in the DMF are negative, giving the impression that the growth of the GNP, depicted e.g. in Figure 36, was not based on increasing use of materials. Basing on the development of these indicators during the 1990s, I make a rough forecast up till 2030. It should be borne in mind that these projections exclude any possible major future developments, such as technological innovations and developments. The results are presented in Figure 37 and in Statistical Appendix 15.

As can be seen from Figure 37, the DMF per capita shows a slightly declining trend towards 2030 and the TMF per capita quite a stabilised one. However, the trend for carbon dioxide emissions up till 2030 is an increasing one. As a conclusion it can be said that the materials required by production (DMF) seem to decline slightly, but the overall materials flow (TMF)

Table 10.
Annual increases of environmental indicators per capita in Finland during certain periods (per cent)

	During 1960s	During 1970s	During 1980s	During 1990s	During 1960–2000	During 1975–2000	During 1985–2000
DMF pc	+3.53	+1.02	+ 1.43	– 0.47	+ 1.29	+ 0.18	+ 0.09
TMF pc	+2.93	+1.27	+ 1.19	+ 0.02	+ 1.40	+ 1.42	+ 0.04
CO_2 pc	+10.29	+3.28	– 0.44	+ 0.70	+ 3.10	+ 0.13	+ 0.10

Figure 37.
Trends of DMF, TMF and CO_2 per capita in 1960–2000 and scenarios till 2030 (1960=100)



seems to remain almost unchanged and carbon dioxide (CO_2) emissions will continue to grow. From the eco-efficiency point of view, the total environmental burden of economy is of great importance. Yet, as CO_2 emissions continue to grow, the TMF shows no changes although the amount of materials actually used by production is declining.

Consequently, I have drafted out four alternative scenarios of the future development of the Finnish DMF. The first scenario, *Scenario 1*, represents the case where the DMF is determined by the scenarios of the GDP and Eco-efficiency 1, i.e. the GDP per DMF ratio, up till 2030. In *Scenario 2* the future trend of the DMF is forecast from its past development during the 1990 – 1999 period. *Scenario 3* is based on the environmental space concept, favoured by many ecological economists, where the size of the DMF is determined by the future population trend, the trend of the DMF over the 1990 – 1999 period, and the per capita DMF in 2000. *Scenario 4* represents the desired path of environmental policy for the attainment of the Factor 4 target, i.e. a 75 per cent reduction in materials use by 2025.

The data for *Scenario 1* are acquired by calculating an estimate of the DMF in 2030 while assuming that the development of the GDP during 1985–2000, as presented e.g. in Figure 19, and that of Eco-efficiency 1, as presented in Figure 23, will materialise. Subsequently, a linear trend toward this estimate has been calculated. *Scenario 2* is obtained from the earlier forecast for the DMF, presented previously in Figure 37. *Scenario 3* is based on the environmental space thinking as it assumes that the 2000 per capita DMF is maintained and the total DMF is achieved by multiplying this per capita DMF by the official population forecast for the corresponding year. This total is further corrected in each coming year by the decrease in the average annual per capita use during the 1990s. As a formula, *Scenario 3* can be expressed as (6.2.1):

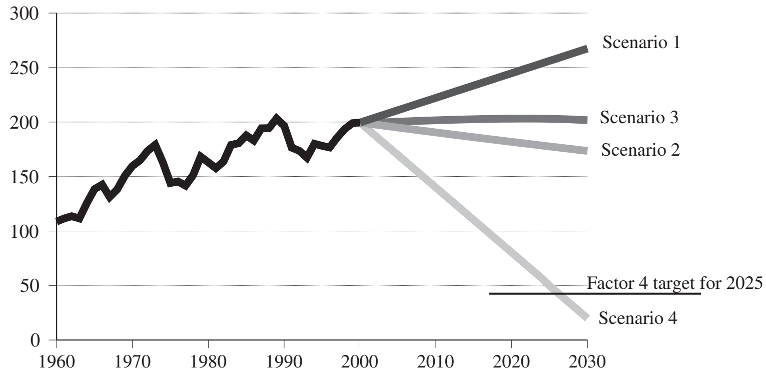
(6.2.1) $DMF = (1 + a) \times (ES \times POP)$

where a is the average annual change in per capita DMF,
ES is the environmental space of an individual, i.e. the average amount of DMF used by an individual, and
POP is the forecast population data for Finland.

In the formula, the value of a = –0.4650371 is used as the multiplier. In Finland, official population forecasts are carried out by Statistics Finland. The corresponding progress of the average number of population in Finland during the period 1960–2000 and a forecast made by Statistics Finland for the 2001–2030 period are also presented in Statistical Appendix 16. According to the forecast, the population growth in Finland is slowing down and a decrease will start in 2022. The number of employed persons will fall even more drastically due to technological changes and the ageing of the population starting in 2008. In contrast to the other scenarios, *Scenario 4* is based on the more or less wishful thinking that Finland will achieve the Factor 4 target by 2025. In other words, *Scenario 4* illustrates the Factor 4 target, or a 75 per cent decrease in the total DMF by 2020–2030. These Scenarios 1, 2, 3 and 4, with a line indicating the actual Factor 4 target (in millions of tonnes) for 2025, are presented in Figure 38.

Figure 38 presents four alternative scenarios of the development of the Finnish DMF and the desired Factor 4 target. *Scenario 1* represents an alternative where the DMF follows the growth of the GDP and the forecasts for Eco-efficiency 1. Thus, it is pertinent to bear in mind that this alternative largely excludes the technological developments to be made in the economy. Furthermore, it receives no support from Figure 37, which shows an alternative forecast for the DMF. *Scenario 2*, which was also presented in Figure 37 and is based on the past development of the DMF, shows an anticipated decrease in the total DMF which is, nevertheless, far from sufficient to comply with the Factor 4 target. *Scenario 3* represents an alternative where the current "environmental space" of the Finnish people and the reduction in materials use are maintained, i.e. the development of the DMF is tied to population forecasts and past reductions in materials use. The trend

Figure 38.
Scenarios 1–4 of the development of Finnish DMF up till 2030 (Million tonnes)



in this scenario is stable and does not promise any reductions in the materials use or DMF in the future. Finally, *Scenario 4* describes a direct, simplified path to achieving Finland's Factor 4 target and if we compare it to the other scenarios we find it unrealistic as such. However, its main benefit is that it concretises the desired path toward sustainable development.

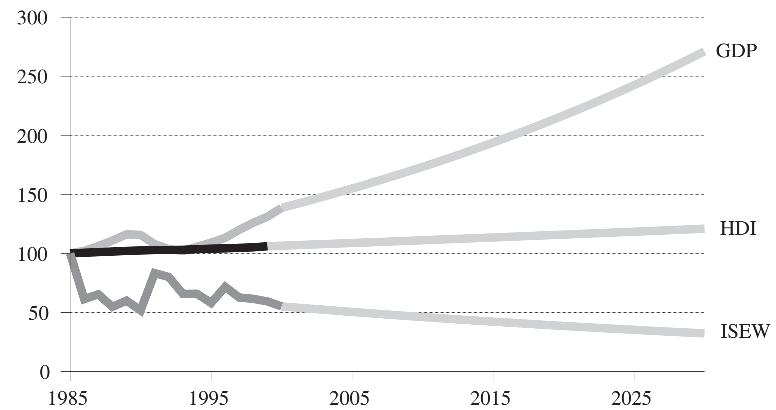
The different eco-efficiency indicators, drafted in Section 5.4, give different perspectives to the actual eco-efficiency achieved in the Finnish economy, since they measure different dimensions of welfare. Thus, it is most interesting to compare their past developments and draft scenarios for their future developments. The scenarios also enable comparisons and conclusions to be made about the future trends of overall eco-efficiency. In Section 5.3, it was concluded that the average annual growth of the Finnish GDP during the 1975 to 2000 period was 2.26 per cent while those of the EDP1 and EDP2 were 2.21 per cent and 2.30 per cent, respectively. Thanks to the economic developments, the HDI grew by 0.39 per cent and the ISEW by 0.08 per cent annually. At the same time, the average annual population growth was 0.38 per cent. Based on these facts the economy seems to have been working quite well during this period. However, in Section 5.3, the ISEW indicator (Figure 20) revealed a dramatic downward change in the population's economic well-being after the early 1980s. Keeping this in mind it would seem preferable to analyse the development during the period starting from 1985 to the present day. During this period, the average annual growth of the Finnish GDP was 2.26 per cent while that of the EDP1 was

2.31 per cent and that of the EDP2 2.69 per cent. The average annual population growth was 0.39 per cent. Meanwhile, the HDI grew by 0.42 per cent but, at the same time, the ISEW decreased by 1.77 per cent annually. Because the number of employed persons decreased annually by an average of 1.53 per cent during the 1988 to 1997 period, the obvious conclusion is that as the number of employed persons decreased, so did also the economic welfare received by people, on average.

Moreover, the annual changes presented in Tables 5 and 6 give an overall impression of the direction of the development of welfare. Future scenarios of the development of the welfare indicators can be drafted on the basis of their past history. The annual average changes of these indicators during the 1985 to 2000 period and data from 2001 were utilised here to draw a simple presentation based on the compound-to-interest method. Although a quite robust method, it enables us to visualise where the current trends of the development lead to by producing some estimates about the magnitudes of the variables in the future. Figure 39 presents actual data concerning the Finnish GDP, HDI and ISEW per capita in 1985–2000, and forecasts for them for the 2001–2030 period based on the developments during 1985 to 2000. The data are also presented in Statistical Appendix 17.

As can be seen from Figure 39 (see the GDP trend), these kinds of estimates have a strong general tendency to "explode". However, this tendency cannot be found from the trends of the ISEW and HDI indicators, which appear quite stable. The Finnish ISEW shows a slightly descending trend and the Finnish HDI a slightly ascending trend. As a conclusion it can be said

Figure 39.
Trends of GDP, HDI and ISEW per capita in 1985–2030 (1985=100)

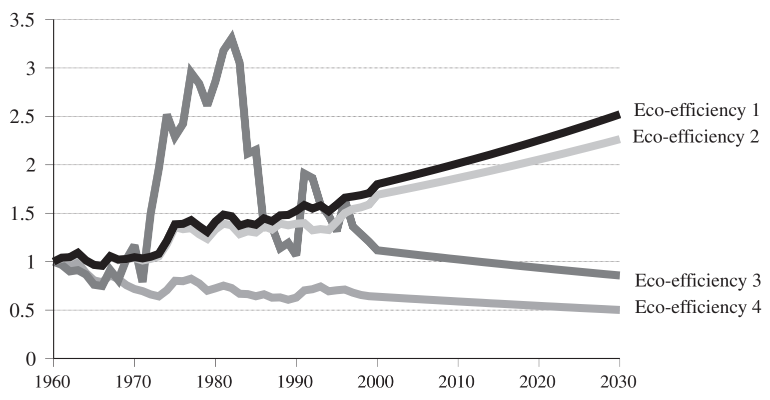


that the production of the Finnish society expressed in monetary terms will continue its growth at the same time as economic welfare will decline somewhat and human potential will grow slightly. As the GDP is growing, the most obvious reasons for this development are growing inequalities of income distribution, urbanisation and its costs, as well as deterioration of the environment i.e. lack of effectiveness of political decision-making processes.

Having now drafted future scenarios for the variables used in the Eco-efficiency 1, 2, 3 and 4 measures, its is now time to draw scenarios for the Finnish Eco-efficiencies 1, 2, 3 and 4 as well, by using the very same technique. It must, however, be borne in mind that these indicators show several different directions depending on the choice of the welfare perspective. The scenarios for Eco-efficiencies 1, 2, 3 and 4 for the 2001–2030 period shown in Figure 40 are based on the past average annual changes of each eco-efficiency indicator during the 1975–2000 period, as presented earlier in Table 8. The data are also presented in Statistical Appendix 18.

Figure 40 shows that Eco-efficiency 1, i.e. *Eco-efficiency of Production*, and Eco-efficiency 2, i.e. Industrial *Eco-efficiency*, of Finland are progressing towards a positive direction. However, the speed of the development is not sufficient, because the Factor 4 and 10 targets would require a 3.3 -fold increase in the average annual eco-efficiency growth. Eco-efficiency 3, i.e. *Societal Eco-efficiency*, and Eco-efficiency 4, i.e. *Human eco-efficiency*, show that the diminishing use of materials in the industrial production of society seems to neither directly benefit the overall social welfare of society nor increase the overall human potential for welfare. It can, therefore, be

Figure 40.
Progress of Eco-efficiencies 1–4 in Finland and forecasts for 2000–2030



concluded that the economic system, although showing some progress towards eco-efficiency lines, does not directly lead to an increase in the overall individual welfare level. Since the distribution of income, health care and education are mainly implemented by society in Finland, we can see that during the 1990s the democratic processes steered resources to other sectors of the society and consequently neglected these issues. In other words, the inefficiency of Finnish society to reach the situation where the optimal level of welfare reached is more evenly distributed to the individuals seems to remain a major problem in the early 2000s.

To summarise these findings, we can now argue that, with the current path of development, the likelihood of achieving the Factor 4 target in Finland seems small. Some reductions in the total Finnish DMF by 2025 can be expected but they will be far from sufficient. Future developments could be characterised by stating that any improvements in eco-efficiency will, therefore, mainly come from increases in welfare, whereas the material input and DMF will remain relatively stable. However, having said this we must also remember that further technological developments and improvements in materials use efficiency are excluded from these scenarios. The continuos technological improvements allowed for in these scenarios may well prove too modest and the actual trajectory remains to be seen.

What comes to the previous eco-efficiency analysis we can state that, on the basis of empirical evidence, the environmental deterioration potential of the Finnish economy, which I fixed to the DMF, has no direct link to the actual level of welfare in the Finnish society as measured with the ISEW and HDI indicators. Linkages can be found between the DMF and the GDP. The forecasting techniques produced very different scenarios of future developments depending on the variables the progress was linked to. The tendency of the GDP to live “a life of its own” clarifies the fact that the GDP growth is based on an ever increasing volume of external effects that are not taken into consideration. Although major environmental drawbacks are included in the EDP1 and EDP2 measures, the very nature of environmental effects is changing and it may be that an inability to track and measure them correctly causes this optical illusion of growth. Taking into account all of the external effects at their full weight could change the picture dramatically.

To summarise this discussion, we can draw the general conclusion that the current trends of development do not indicate that the Factor 4 target could be reached by 2025 without further actions aimed toward improving the eco-efficiency of Finnish economy. What then could be done in order to foster the eco-efficiency of Finnish economy towards the Factor 4 and 10 targets? These actions can be divided into three categories, namely, (a) technological improvements in production policies, (b) environmental policy actions aiming to reduce the use of materials, and (c) social policy actions aiming to even out the distribution of the wealth generated. Obviously, the most efficient policy would be a mix of all these actions. From the economics point of view, technological improvements can best be fostered by raising the prices of natural resources and energy. This will encourage the development of more efficient production techniques. Therefore, this question of technology eventually turns out to be an economic policy question, too. Environmental policy aiming towards reduced use of materials could also include administrative and information measures and a parallel social policy targeted towards even income distribution, taxation and subsidising measures. Environmental and social policy actions especially would require that the vital importance of the demands of eco-efficiency to our well-being is recognised in democratic processes and the resulting policies are formulated accordingly.

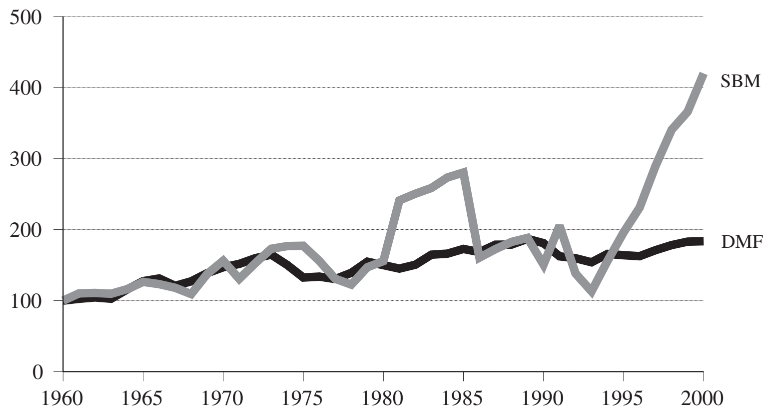
6.3 Future trends of the Finnish eco-efficiency potential

With regard to the use of the SBM as a measure of welfare in an eco-efficiency analysis, it is now interesting to compare the development of the SBM to that of the Direct Material Flow (DMF) of the Finnish economy. The presumption that the SBM has also remained constant in relation to the total DMF of Finnish society receives some affirmation from the following Figure 41.

As can be seen from Figure 41, the trends of the SBM and DMF were quite similar in the 1960s and 1970s. However, during the 1980s and early 1990s this linkage disappeared as fluctuations in the SBM grew. There seems to be no linkage between the SBM and DMF after 1993. Besides this kind of analysis, the SBM can also be utilised as a measure of welfare in an empirical study of the eco-efficiency analysis. In the following analysis, the SBM is used as an output while the Direct Material Flow (DMF) is utilised as an input. I have studied the eco-efficiency of Finnish economy by using the following Eco-efficiency 6 (or EE6) formula (6.3.1). (For further details see Adriaanse et al. 1997, 14):

$$\text{(6.3.1)} \quad \text{Eco - efficiency 6} = \frac{\text{SBM}}{\text{DMF}}$$

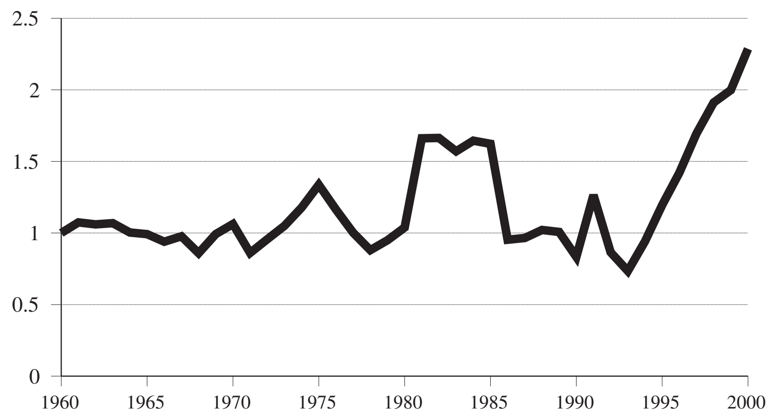
Figure 41.
Sustainable net benefit measure and direct material flow in Finland (1960=100)



The results obtained using formula (6.3.1), or the *SBM/DMF* ratio, are presented in Figure 42 and in Statistical Appendix 19.

As can be observed from Figure 42, the trend of Eco-efficiency 6 of Finnish economy remained a somewhat constant until 1995 after which it improved clearly as viewed through the SBM measure. Compared to 1960, by 2000 Eco-efficiency 6 had improved by a total of 129.7 per cent. How-

Figure 42.
Eco-efficiency 6 of Finnish economy



ever, in 1993 Eco-efficiency 6 was 26.5 per cent below the 1960 level and the situation was corrected only by rapid improvements in the late 1990s. During the period 1993 to 2000, the improvement in Eco-efficiency 6 amounted to 156.2 per cent and the average annual improvement to 19.5 per cent. Generally, the average annual improvement of Eco-efficiency 6 was 14.0 per cent during the 1990s. In Figure 43, Eco-efficiency 6 is compared to Eco-efficiency 2, presented earlier in Chapter 4. Eco-efficiency 2 (or EE2) is based on the EDP1/DMF ratio whereas Eco-efficiency 6 (EE6) refers to the SBM/DMF ratio.

As can be seen from Figure 43, the Eco-efficiency 6 measure shows an improvement in Finnish eco-efficiency during the 1990s and thus it indicates the most promising prospect for an eco-efficient future so far. Figure 44 provides two different scenarios based on the Eco-efficiency 2 and 6 measures of the development of Finnish eco-efficiency up till 2025. The forecasts are based on the development of each eco-efficiency measure during the time period from 1985 to 2000.

As can be seen from Figure 44, the projections for Eco-efficiency measures 2 and 6 up till 2025, based on development during 1975–2000, give very different outlooks for the achievement of the Factor 4 target. We can now conclude that the SBM-based Eco-efficiency 6 measure suggests a very promising prospect for achieving the Factor 4 target by 2025. This is thanks to the positive development accomplished during the 1990s. However, whether this is a real turning point in history, or only a short-term adjustment, remains to be seen.

Figure 43.
Development of Eco-efficiencies 2 and 6 of Finnish economy

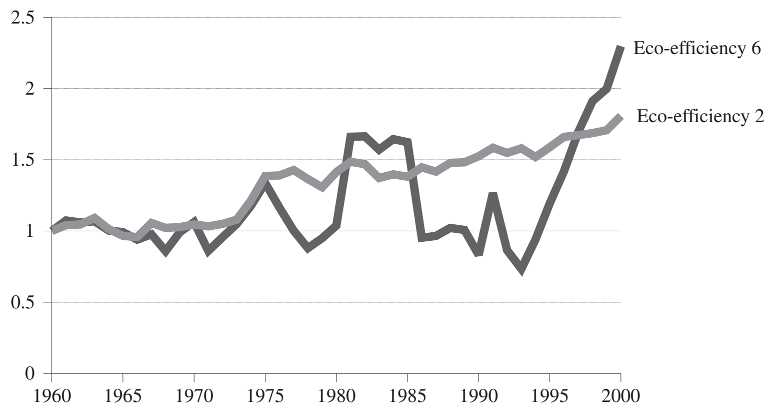
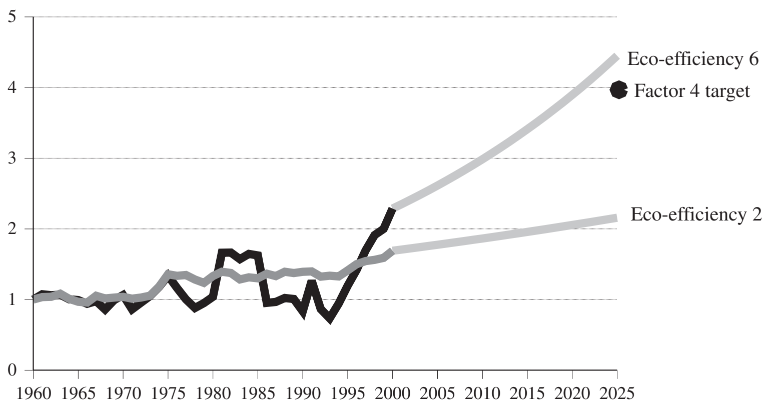


Figure 44.
Forecast of Eco-efficiencies 2 and 6 of Finnish economy till 2025



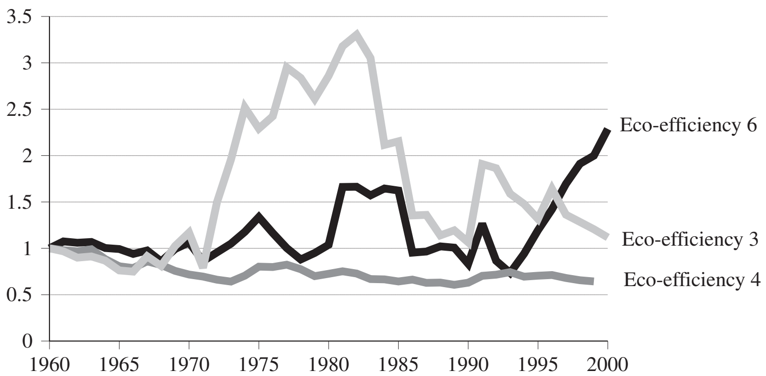
6.4 Improving the measurement of eco-efficiency

The SBM measure, presented in Section 6.1 and used in the subsequent eco-efficiency analysis in Section 6.3, proved to be a more suitable measure of welfare for eco-efficiency analysis than, for example, the ISEW and HDI because it is a production-based measure of welfare. From the economics point of view it is a far better measure of the benefits actually created by production as it takes into consideration most of the external effects of economic growth. The conventional GDP and EDP1 measures bypass many of these factors. Thus, the SBM is a better measure of the benefits created in production. From the purely welfare point of view, the SBM bypasses the income distribution dimension of welfare, which is included in the ISEW. The distribution of income in society is normally accomplished with purely political decisions, which in many cases have no direct links to the wealth creating process, i.e. the production itself. Thus, the SBM is a poorer measure than the ISEW of the welfare actually received by individuals. However, for the very same reason the SBM is a better measure than the ISEW of the outcome of the wealth creating process.

From the eco-efficiency point of view it is important that the measure of welfare utilised is tied to the actual benefits from the production process, or the economy itself as SBM. The distribution of the welfare generated then depends on the third dimension of the eco-efficiency approach, i.e. social justice, equality and ethics. Therefore, it should be borne in mind that the eco-efficiency approach also includes the dimensions of social justice, equality and ethics. This aspiration for increasingly equitable welfare distribution, which is one of the core ideas of sustainable development, is partly taken into account by the ISEW indicator. Whereas the SBM offers a picture of the "welfare potential" that production offers, the ISEW comes closer to the idea of measuring some of the progress of equality. Nevertheless, the ISEW concentrates on the economic equality and excludes some vital factors of welfare, such as life expectancy, education, justice and overall happiness of individuals. The HDI indicators cover also these factors, albeit insufficiently. Therefore, it is not justified to only stare at the Eco-efficiency 6 (EE6) measure which is based on the SBM/DMF ratio. The Eco-efficiency 3 (EE3) and 4 (EE4) measures (ISEW/DMF and HDI/DMF ratios) presented earlier in Section 5.4 also elucidate the progress of the third dimension of the eco-efficiency approach in Finland. Figure 45 presents the development of Eco-efficiencies 3, 4, and 6 in Finland.

Figure 45 summarises some of the main findings of this study. It shows Eco-efficiency 6 which describes "eco-efficiency potential", Eco-efficiency 3 which describes eco-efficiency when equality of welfare distribution is taken into consideration, and Eco-efficiency 4 which describes how efficiently the DMF contributes to education and human knowledge. By analys-

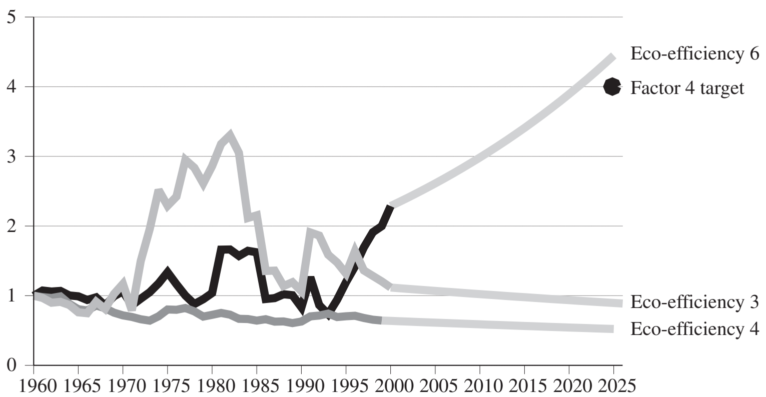
Figure 45.
Trends of Eco-efficiencies 3, 4 and 6 of Finnish economy



ing the past trends it can be concluded that the development of the DMF does not appear to contribute to the growth of human knowledge, i.e. this ratio is clearly inefficient. In the early 1960s, the equality of the distribution of economic welfare lagged behind the welfare potential, but in the early 1970s, the trend of Eco-efficiency 3 shows a huge upward swing. However, by the mid-1980s Eco-efficiency 3 plummets down following the fall of Eco-efficiency 6. Recovery of Eco-efficiency 3 coincides with the economic recession of the early 1990s, and diminishing use of materials contributes greatly to this situation. However, because of the heavy financial intervention of the state by way of unemployment and social security benefits, the upsurge of Eco-efficiency 3 cannot be viewed as very sustainable.

The situation in the 1990s gives controversial answers to questions about the future progress of eco-efficiency in Finland. The trend of Eco-efficiency 6 suggests achievement of the Factor 4 and 10 targets, as desired. This viewpoint is possible thanks to declining trends in the external effects of production and the DMF. At the same time, the distribution of welfare is not progressing towards an equitable direction and the slight growth of human development, or knowledge, lags behind the decline of the DMF. To summarise, although economic and environmental efficiencies seem to materialise, the progress of the third dimension of eco-efficiency, i.e. equitable welfare, justice and ethics, shows a stagnant, or even declining, trend. This becomes highly apparent from Figure 46, which presents forecasts, based on the actual development in 1975–2000, for Eco-efficiencies 3, 4 and 6 of Finnish economy up till 2025. The data are also presented in Statistical Appendix 19.

Figure 46.
Forecast of Eco-efficiencies 3, 4 and 6 of Finnish economy till 2025



As can be seen from Figure 46, projections of the Eco-efficiency 3, 4 and 6 measures up till 2025, based on development in 1975–2000, give very different outlooks for the achievement of the Factor 4 target. If the DMF and the external environmental effects of production will continue declining as they did in the 1985–2000 period and the GDP will continue to grow, Finnish economy may very well indeed achieve the desired Factor 4 and 10 targets. The real bottleneck of the development towards sustainable society is, however, the use of the generated "potential welfare". Political decisions about even welfare distribution are desperately needed if we want to achieve a society conforming to the idea of sustainable development.

7 Conclusions

As a environmental policy concept, eco-efficiency combines sparing use of natural resources and environmental policy objectives with economic efficiency with the aim of reducing the volume of natural resources that are used in order to alleviate the consequences from the overburdening of the environment. During the phase of industrialisation, environmental dimensions, such as materials use, were neglected issues in societal policies and they were not taken into consideration since the price mechanism of economics did not appreciate them. Today, many researchers argue that the impact of the explosively intensifying exploitation of natural resources on the environment already exceeds the sustainable production of many environmental systems today. Overexploitation of natural capital has resulted in undesirable environmental impacts. In its conventional sense, sustainability means maintaining the environmental assets, or at least not depleting them. Eco-efficiency aims to secure a decent, equitable welfare to all individuals and, at the same time, reduce environmental degradation to a level that is sustainable. Thus, the eco-efficiency approach seems like a promising action strategy for the strive towards sustainable development. However, although the possibilities of eco-efficiency have largely been recognised at the economy level, its proficient measurement is yet to be developed. In principle it is possible to measure the overall eco-efficiency of an economy to get an overall picture about the direction of development for the use of policy implementation of a society. Such monitoring fills a gap that has been neglected until the 1990s in the state of environmental monitoring. It is still a matter of dispute whether this can be done using a single measure. In industrialised economies, the use of a set of indicators modified to comply with national circumstances for describing different dimensions of eco-efficiency seems preferable.

In this study the eco-efficiency analysis has shown its usefulness in assessing the performance of several industrial economies. The benefits of the eco-efficiency approach are numerous. First of all, practical applications of the eco-efficiency analysis provide new understandings of the physical basis of a society and of the welfare generation processes of western societies. Second, pricing of natural assets is not needed and thus many problems of artificial pricing methods and practices can be bypassed. It is only some welfare indicators, like EDP2, ISEW and SBM that require the use of some sort of artificial pricing methods. Third, economic activities and natural resources flows can be combined into a single overall picture describing their interaction. Drawbacks of the eco-efficiency approach relate to the uncertainties and problems of practical measurements. From the biological viewpoint, the use of a small amount of some highly toxic substance in the economy may have a greater impact than the use of a much larger amount of relatively harmless stone. As a result, the summation of various material tonnages into a single measure provides only a very rough picture of the state of the environment and it can easily be accused of being irrelevant because the uses of different materials have different environmental implications. For example, some environmental scientists feel uncomfortable about summing up masses of different materials since there is no universally accepted weighting system for balancing out the environmental effects of the different materials. Yet, without this kind of simplifying hypothesis, the opportunity for making macro-scale analyses and international comparisons on materials use will be lost. These shortcomings should be kept in mind when aggregated materials measures are used in the eco-efficiency analysis. However, the eco-efficiency analysis provides the only estimates of changes in the materials use in welfare generation that are produced in a consistent and reliable way. Thus, these estimates are the most reliable for the analysis of the structure of the materials use of an economy.

I review the trends in eco-efficiency in Finland as well as in Germany, USA, Japan, Austria, the Netherlands and Sweden by using several different eco-efficiency measures. In its simplified form, eco-efficiency formula expresses output in relation to expenses, i.e. eco-efficiency is yield over cost. The larger this figure is, the more efficient and productive is the function concerned. At the level of the whole economy the nominator in the eco-efficiency formula should represent "the improvement in quality of life" that includes a wide variety of social phenomena which are not measurable. I used the Gross Domestic Product (GDP), Environmentally adjusted Domestic Product (EDP1), Index of Sustainable Economic Welfare (ISEW) and Human Development Indicator (HDI) as well as the Genuine Progress Indicator (GPI) as measurable proxies of welfare. As denominator of the eco-efficiency formulas I used the Direct Material Flow (DMF) measure that is a highly aggregated and rough background indicator of all the materials used in the economic activities of a society. However, the DMF is comparable to the GDP in economic terms. The Total Material Requirement (TMR) or Total Material Flow (TMF) measures, which also include unused resources (hidden flows) in an aggregate indicator, are excluded from this study since in comparisons between countries the hidden flows are included under output in the country of export and under imports in the country of import despite the fact that the resources involved are used only once. The TMR measure is also quite a problematic one, since the sensitivity of the TMR to the size of external trade reduces its informative value as an indicator. The same difficulty confuses the TMF's overall picture of the materials use of an economy. Since my focus is on the analysis of economic welfare I exclude the Total Material Flow (TMF) indicator from this study.

The practical eco-efficiency analysis showed that different welfare indicators give different pictures of the development of overall welfare in society. This problem also influences the eco-efficiency results obtained from the analysis. A particular problem is that these aggregate indicators, like the GDP, ISEW and HDI, can all point to different directions at the same time depending on the progress and direction of the welfare dimension they represent. As the GDP measures the level of production excluding the external effects of production, the ISEW emphasises the economic possibilities of individuals and the HDI appreciates the factors of well-being that tell about the long-range future possibilities for economic development. The ISEW appears to be the best indicator of welfare, as the GDP measures the level of production that does not in most cases contribute to the welfare of the people and the HDI, which emphasises such public factors of development as education and health services, is clearly more suitable for developing countries. However, the ISEW fails to follow the growth of the human capital and its future potential. This inability to identify future potential is a major weakness of the ISEW. The environment perspective is best observed by the ISEW. The EDP1 derivative of the GDP fails to emphasise the environmental hazards adequately because of the problem of pricing. However, the GDP and EDP measures have as their starting point the premise that economic welfare originally comes from production. The ISEW and HDI indicators are, in fact, based on political decisions about how produced assets are re-allocated in society.

As a consumption-based measure the ISEW is independent from the value added generated by production in short-term periods and thus mainly determined by political decisions concerning income distribution. Exclusion of the fairness of income distribution policies is necessary to achieve meaningful results concerning the actual economic-environmental eco-efficiency. For this purpose I designed a better aggregate measure of the gains achieved through production activities. This new aggregate measure aims to present a more reliable estimate of the progress of actual gains from economic growth and, at the same time, avoid the income distribution confusion of the ISEW originating from political decisions. Thus, the new measure gives an overall picture of the wealth generated and bypasses the social policy problems of income distribution, taxation and social welfare subsidies. I named this new measure the Sustainable net Benefit Measure of production (SBM). The SBM takes as its starting point the conventional GDP, from which "Incomes from ROW" and "Consumption of fixed capital" are subtracted in order to arrive at the SNA's conventional Net National Income, or NNI, measure. After that, and as in the ISEW, all environmental and human life drawbacks are subtracted from the NNI in order to obtain the SBM. The point of departure of the SBM is the Net National Income (NNI) concept of the SNA, from which four major negative components are subtracted. Total environmental expenditure of society (TE) includes all costs of environmental protection activities by the state, municipalities, industry and NGOs. Negative side effects of economic growth (NE) include expenditure on national advertising, and the costs of commuting, urbanisation and motoring accidents. Changes in natural resources (NR) include growth and carbon binding of forests, and acid deposition and defoliation of forests. Other changes in ecosystems (OE) include the costs of water, air and noise pollution, loss of wetlands and farmland and long-term environmental damage. As such, the SBM combines elements from both the EDP and ISEW calculation methods.

I utilised the scenario technique to produce projections for the eco-efficiency indicators in the near future. The best known quantitative goal of eco-efficiency is achievement of the Factor 4 and 10 targets, which initially means achieving a 75 per cent decrease in materials use during the next 20–30 years and a further reduction down to 90 per cent during the following 30–50 years, while maintaining at least the current, or even higher, level of welfare. According to the findings of this study, it seems that, with the current path of development, the likelihood of achieving the Factor 4 targets in Finland seems small when the progress is reviewed through the Eco-efficiency 1, 2, 3 and 4 measures. Although some reductions in the total Finnish DMF by 2025 can be expected, they will be far from sufficient. To summarise the scenarios of the future development of these eco-efficiencies on the basis of past development in the 1985–2000 period, it can be stated that Eco-efficiency 2 (EDP1/DMF ratio) predicts that only half of the target will be reached and thus, it gives a more optimistic view of the future than do Eco-efficiency 1 (GDP/DMF ratio), Eco-efficiency 3 (ISEW/DMF ratio) or Eco-efficiency 4 (HDI/DMF ratio). A sectoral analysis of the eco-efficiencies of Finnish economy (value added/sector's DMU ratio) reveals that the development in society is not parallel, but divergent. During the 1990s, Eco-efficiency 5 of civil engineering and manufacture of complete constructions, etc., remained quite stable. The eco-efficiency of the basic metal industry, quarrying and mining, pulp and paper industry as well as transport have improved clearly during the 1990s.

Future developments could be characterised by stating that any improvements in eco-efficiency will, therefore, mainly come from an increase in welfare, whereas the materials input and DMF will remain relatively stable. However, it should be remembered that further technological developments and improvements in materials use efficiency are excluded from these scenarios. The continuous technological improvements allowed for in these scenarios may well prove too modest and the actual trajectory remains to be seen. The projection for the Eco-efficiency 6 measure (SBM/DMF ratio) up till 2025, based on the development during 1985–2000, offers a very promising prospect for achieving the Factor 4 target by 2025. In fact, the Eco-efficiency 6 measure seems to suggest achievement of the Factor 4 targets by 2020–2030. This is thanks to the positive development of welfare (measured through the SBM indicator) accomplished during the 1990s. However, whether this is a real turning point in history, or only a short-term adjustment, remains to be seen. This development of Eco-efficiency 6 owes a great deal to the fact that the DMF is gradually diminishing and improvements in the SBM are bound to decrease the extent of environmental hazards. To summarise, if we wish to measure the eco-efficiency of an actual production process or the materials efficiency of production processes, the SBM is a far better measurement of welfare than the GDP, EDP, HDI or ISEW are. The SBM can also be interpreted as representing the "potential welfare". However, if the desire is to also include in the eco-efficiency analysis the progress of the third dimension of eco-efficiency, i.e. equitable welfare, justice and ethics, then the ISEW and HDI are more useful measures of the actual welfare, or well-being, received by individuals since they also include some of these components.

Several conclusions can also be drawn concerning achievement of the Factor 4 target in 2025. In fact, the current trends of development suggest that the Factor 4 target can be reached by 2025 without further actions aimed toward improving the eco-efficiency of Finnish economy. However, the third dimension of eco-efficiency, i.e. equitable welfare, justice and ethics, requires political decisions about more even and fair income distribution aiming to smooth the distribution of the wealth generated. The other actions required include (a) improvements in production technologies and (b) environmental policy actions aiming to reduce the use of materials. Obviously, the most efficient policy would be a mix of all these actions. Further research and development is also needed concerning the eco-efficiency analysis in the field of welfare measurement and different materials' potential to cause environmental hazards.

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APPENDIX 1.
Progress of GNP, population, use of fossil fuels and emissions of carbon dioxide in Finland in 1860–2000

	GNP Volume (1926=100)	Population (1,000)	Fossil fuels (PJ)	Emissions of CO_2*) (mill. t.)
1860	20.9	1,770.6	0.4	0.03
1861	21.0	1,786.2	0.7	0.06
1862	19.9	1,797.4	0.7	0.06
1863	21.5	1,827.0	0.8	0.07
1864	22.0	1,843.2	0.5	0.04
1865	21.8	1,837.5	0.6	0.05
1866	22.1	1,824.2	0.7	0.06
1867	20.3	1,727.5	0.6	0.06
1868	22.3	1,739.6	0.9	0.08
1869	23.9	1,768.8	0.7	0.06
1870	25.0	1,803.8	0.9	0.08
1871	25.2	1,834.6	1.1	0.10
1872	26.1	1,860.0	0.9	0.08
1873	27.6	1,886.1	0.9	0.08
1874	28.2	1,912.7	1.3	0.12
1875	28.8	1,942.7	0.8	0.08
1876	30.4	1,971.4	0.9	0.09
1877	29.7	1,994.6	1.2	0.11
1878	29.1	2,032.7	1.3	0.12
1879	29.4	2,060.8	0.8	0.07
1880	29.6	2,082.6	1.0	0.09
1881	28.8	2,113.3	1.0	0.09
1882	31.6	2,146.4	1.2	0.11
1883	32.8	2,180.6	1.2	0.11
1884	33.0	2,208.5	1.4	0.13
1885	33.8	2,238.6	2.2	0.20
1886	35.5	2,278.1	1.4	0.12
1887	36.1	2,314.2	1.4	0.12
1888	37.4	2,347.7	1.3	0.11
1889	38.7	2,380.1	1.7	0.15
1890	40.9	2,408.3	2.2	0.19
1891	40.5	2,422.5	2.3	0.20
1892	39.3	2,436.7	2.0	0.18
1893	40.8	2,465.7	2.1	0.18
1894	44.0	2,499.9	2.3	0.20
1895	46.4	2,530.9	2.5	0.22
1896	49.4	2,567.5	3.1	0.28
1897	51.8	2,610.3	5.3	0.48
1898	54.1	2,635.3	5.0	0.45
1899	52.8	2,655.9	7.5	0.68
1900	55.3	2,678.5	6.1	0.55
1901	54.6	2,693.9	4.4	0.39

APPENDIX 1. cont.

	GNP Volume (1926=100)	Population (1,000)	Fossil fuels (PJ)	Emissions of CO_2*) (mill. t.)
1902	53.5	2,717.1	4.2	0.37
1903	57.1	2,751.9	5.3	0.48
1904	59.3	2,773.0	5.5	0.49
1905	60.2	2,803.7	6.1	0.55
1906	62.6	2,838.7	6.4	0.57
1907	64.8	2,883.0	9.1	0.82
1908	65.5	2,914.8	14.2	1.30
1909	68.4	2,943.4	13.0	1.19
1910	69.9	2,980.0	10.9	0.99
1911	71.9	3,015.5	13.3	1.22
1912	75.9	3,035.8	15.0	1.38
1913	80.0	3,069.5	16.9	1.56
1914	76.5	3,096.3	7.1	0.64
1915	72.6	3,114.2	1.4	0.11
1916	73.6	3,134.3	2.0	0.16
1917	61.8	3,115.3	1.5	0.12
1918	53.6	3,118.0	2.0	0.17
1919	64.7	3,147.6	2.9	0.24
1920	72.4	3,193.2	4.7	0.40
1921	74.8	3,227.8	5.6	0.48
1922	82.7	3,258.6	7.5	0.65
1923	88.8	3,286.2	9.5	0.83
1924	91.1	3,322.1	12.1	1.06
1925	96.3	3,355.2	14.2	1.25
1926	100.0	3,380.6	15.6	1.37
1927	107.8	3,412.1	18.7	1.66
1928	115.1	3,435.3	22.4	1.99
1929	116.5	3,462.7	25.9	2.30
1930	115.1	3,489.6	32.2	2.87
1931	112.3	3,516.0	33.1	2.97
1932	111.8	3,536.6	35.6	3.22
1933	119.3	3,561.6	38.9	3.51
1934	132.8	3,589.6	44.0	3.96
1935	138.5	3,612.4	45.6	4.10
1936	147.8	3,640.2	49.8	4.47
1937	156.2	3,672.1	56.1	5.02
1938	164.3	3,699.7	60.3	5.38
1939	157.3	3,695.6	58.2	5.17
1940	149.1	3,707.8	36.0	3.25
1941	154.0	3,708.8	15.9	1.41
1942	154.5	3,732.5	13.4	1.17
1943	172.2	3,737.1	15.1	1.32
1944	172.3	3,778.9	27.6	2.52
1945	162.6	3,833.1	13.0	1.17

APPENDIX 1. Cont.

	GNP Volume (1926=100)	Population (1,000)	Fossil fuels (PJ)	Emissions of CO_2*) (mill. t.)
1946	175.5	3,885.3	41.0	3.70
1947	179.6	3,937.8	59.5	5.27
1948	193.8	3,988.0	71.6	6.33
1949	205.6	4,029.8	74.5	6.58
1950	213.5	4,064.7	80.0	7.06
1951	231.7	4,116.2	86.7	7.60
1952	239.4	4,162.6	87.5	7.62
1953	241.1	4,211.2	93.4	8.10
1954	262.2	4,258.6	99.6	8.53
1955	275.6	4,304.8	121.0	10.30
1956	283.9	4,343.2	140.7	11.81
1957	297.3	4,376.3	144.4	12.09
1958	298.9	4,413.0	141.5	11.79
1959	316.6	4,446.2	155.3	12.90
1960	345.6	4,475.8	174.1	15.46
1961	372.0	4,507.1	175.8	15.45
1962	383.0	4,539.5	194.8	16.92
1963	395.5	4,557.6	227.5	19.44
1964	416.4	4,569.9	257.1	22.56
1965	438.4	4,591.8	292.0	25.38
1966	448.8	4,619.6	340.9	28.48
1967	458.6	4,633.3	347.1	28.88
1968	469.1	4,614.3	394.5	32.37
1969	514.1	4,598.3	464.1	38.41
1970	552.5	4,625.9	508.5	39.87
1971	564.1	4,653.4	511.8	39.77
1972	607.1	4,678.8	559.9	43.59
1973	647.9	4,702.4	619.2	48.25
1974	667.5	4,720.5	568.7	44.15
1975	675.2	4,730.8	574.2	44.09
1976	672.3	4,747.0	652.3	50.43
1977	674.0	4,758.1	642.1	49.76
1978	688.1	4,771.3	687.6	54.00
1979	735.9	4,787.8	681.6	53.50
1980	775.2	4,812.2	685.9	54.28
1981	789.6	4,841.7	578.3	45.06
1982	815.3	4,869.9	552.6	43.48
1983	837.3	4,894.0	543.8	43.07
1984	862.6	4,911.0	557.8	44.48
1985	891.6	4,925.6	628.4	50.45
1986	912.8	4,932.0	614.5	48.96
1987	950.2	4,954.4	660.1	52.46
1988	996.8	4,974.4	658.7	52.06
1989	1053.3	4,998.5	661.5	51.84

APPENDIX 1. Cont.

	GNP Volume (1926=100)	Population (1,000)	Fossil fuels (PJ)	Emissions of CO_2*) (mill. t.)
1990	1053.4	5,029.0	688.9	53.99
1991	979.0	5,055.0	681.3	53.27
1992	944.2	5,077.9	655.9	51.40
1993	933.1	5,098.8	668.9	52.00
1994	974.2	5,117.0	742.0	58.30
1995	1015.6	5,132.0	703.3	55.20
1996	1061.3	5,147.0	766.5	61.60
1997	1128.1	5,140.0	745.9	59.80
1998	1188.2	5,154.0	728.4	57.40
1999	1237.7	5,171.3	722.8	56.80
2000	1311.2	5,182.1	698.3	54.80

*) = CO_2 emissions from fossil fuels and peat.

NB. CO_2 emission calculation methods have changed and therefore the figures for 1992–2000 are not directly comparable with earlier data. However, for purpose of time series analysis of this research the aggregated data is accurate enough.

Sources: GNP and population: Statistics Finland. Use of fossil fuels and carbon dioxide emissions: 1860–1989: VTT Energy (Unpublished data) and 1990–2000: Statistics Finland.

APPENDIX 2.
Finland's aquatic discharges of phosphorus, nitrogen and biological oxygen demand (BOD_7) in 1960–2000

	Phosphorus (tonnes)	Nitrogen (tonnes)	BOD_7 (tonnes)
1960	5,407	65,068	442,899
1961	5,626	66,417	479,399
1962	5,601	66,409	461,149
1963	5,720	67,163	479,399
1964	6,168	69,694	552,399
1965	6,343	69,702	570,649
1966	6,383	69,448	552,399
1967	6,428	68,194	534,149
1968	6,549	69,321	552,399
1969	6,677	70,448	561,524
1970	6,810	70,367	570,649
1971	6,781	67,485	494,721
1972	6,737	66,603	534,347
1973	6,747	65,170	444,399
1974	6,517	65,397	435,552
1975	6,212	64,478	348,018
1976	5,739	63,628	319,322
1977	5,199	64,235	297,672
1978	4,490	65,083	231,793
1979	4,170	65,619	247,730
1980	4,240	66,374	247,195
1981	4,393	66,683	258,766
1982	4,456	66,212	258,900
1983	4,403	65,105	256,737
1984	4,595	67,005	256,465
1985	4,727	67,447	231,873
1986	4,761	66,663	188,069
1987	4,958	67,356	177,848
1988	5,133	67,661	172,519
1989	5,217	68,080	154,262
1990	5,221	68,245	128,203
1991	5,048	67,388	109,004
1992	5,042	66,593	100,053
1993	5,002	65,806	89,070
1994	5,093	65,807	79,334
1995	5,144	65,512	66,978
1996	4,916	70,941	57,658
1997	4,690	76,599	55,439
1998	4,702	76,864	54,000
1999	4,291	75,527	51,000
2000	4,259	74,995	50,600

NB. Phosphorus and Nitrogen totals include human-caused discharges from households, industry, agriculture, forestry and fish farming. Natural run-offs, aerial depositions as well as discharges from fur farm production, peat production, etc., are excluded. BOD_7 total includes human-caused discharges from households, industry and fish farming. Other discharge sources are excluded.

Source: The Finnish Environment Institute. (Unpublished data)

APPENDIX 3.

Emissions and depositions of sulphur dioxide and oxides of nitrogen in Finland in 1950–2000 (1,000 tonnes)

	Emissions of sulphur dioxide	Emissions of oxides of nitrogen	Depositions of Sulphur dioxide	Depositions of oxides of nitrogen
1950	78	106	57	33
1951	80	110	..	..
1952	82	114	..	..
1953	83	118	..	..
1954	85	122	..	..
1955	87	126	63	36
1956	113	130	..	..
1957	139	134	..	..
1958	166	138	..	..
1959	192	142	..	..
1960	218	146	192	33
1961	252	153	200	35
1962	284	160	207	36
1963	316	167	215	38
1964	348	174	222	39
1965	380	181	230	41
1966	406	189	238	43
1967	432	197	245	44
1968	458	205	253	46
1969	484	213	260	47
1970	510	221	268	49
1971	557	229	267	51
1972	604	237	266	52
1973	651	245	266	54
1974	610	253	265	56
1975	569	261	264	58
1976	545	268	263	59
1977	538	275	262	61
1978	541	281	262	63
1979	562	288	261	64
1980	584	295	260	66
1981	534	276	252	65
1982	484	271	244	65
1983	372	262	235	64
1984	368	258	227	64
1985	383	275	219	63
1986	331	278	232	79
1987	327	288	191	59
1988	303	293	208	77
1989	242	301	177	75
1990	258	300	153	66
1991	195	290	153	72
1992	141	284	130	66

APPENDIX 3. cont.

	Emissions of sulphur dioxide	Emissions of oxides of nitrogen	Depositions of Sulphur dioxide	Depositions of oxides of nitrogen
1993	122	282	107	55
1994	115	282	105	55
1995	96	258	97	58
1996	105	268	94	57
1997	100	260	94	52
1998	96	252	89	59
1999	85	247	89*)	59*)
2000	74	236	89*)	59*)

*) = estimate.

Sources: 1950–1979: National Board of Waters and the Environment; Ministry of the Environment.
1980–2000: Statistics Finland. (Unpublished data)

APPENDIX 4.
Mining of ores and industrial minerals and quarrying of limestone in 1945–2000 (million tonnes)

	Industrial minerals	Limestone	Ores
1945	–	0.8	0.8
1946	–	0.8	0.7
1947	–	1.1	0.7
1948	–	1.4	0.8
1949	–	1.5	0.8
1950	–	1.8	0.8
1951	–	1.8	1.0
1952	–	1.8	1.1
1953	–	1.8	1,3
1954	–	2.5	1.5
1955	–	2.3	1.8
1956	–	2.2	2.2
1957	–	2.2	2.2
1958	–	2.0	2.2
1959	–	3.2	2.2
1960	–	3.0	2.2
1961	–	3.6	2.8
1962	–	3.4	3.3
1963	–	3.7	3.3
1964	–	4.2	3.7
1965	–	4.3	4.2
1966	0.2	4.3	4.3
1967	0.2	3.9	4.8
1968	0.2	3.7	5.2
1969	0.3	4.3	6.0
1970	0.5	4.8	6.2
1971	0.5	4.5	5.8
1972	0.5	4.5	7.6
1973	0.6	4.8	8.5
1974	0.6	5.5	8.5
1975	0.6	5.0	8.0
1976	0.6	4.6	9.0
1977	0.8	4.8	10.3
1978	0.8	4.8	9.7
1979	1.1	4.7	10.5
1980	3.2	3.2	10.2
1981	3.5	5.0	9.8
1982	4.0	5.3	9.7
1983	6.3	5.8	9.1
1984	7.2	5.7	9.3
1985	7.4	5.8	8.3
1986	7.3	6.0	7.0
1987	8.0	6.2	6.2

APPENDIX 4. Cont.

	Industrial minerals	Limestone	Ores
1988	8.5	6.3	5.2
1989	8.7	6.5	5.6
1990	8.3	5.7	5.5
1991	7.2	5.3	5.5
1992	8.0	4.4	4.7
1993	8.7	4.1	4.9
1994	9.2	3.9	4.6
1995	9.3	3.4	3.2
1996	9.3	3.4	3.4
1997	9.9	3.7	3.5
1998	10.0	4.0	3.2
1999	10.4	3.9	3.1
2000	10.2	3.8	3.3

– = not mined.

Source: Ministry of Trade and Industry. (Unpublished data)

APPENDIX 5.
Progress of DMF and TMF in Finland in 1960–2000 (million tonnes)

	Ores	Stone Mate-rial*)	Fossil fuels and peat	Wood mate-rial	Crops	Others	DMF	Hidden flows*)	TMF
1960	5.2	43.3	6.2	43.5	9.4	1.0	108.7	61.9	170.6
1961	6.4	43.6	6.3	45.7	8.5	1.1	111.6	59.6	171.1
1962	6.7	48.8	6.8	42.1	7.8	1.3	113.6	57.9	171.5
1963	6.6	46.0	7.7	41.6	8.5	1.2	111.6	61.1	172.7
1964	7.5	57.2	9.0	42.9	7.8	1.5	125.8	66.5	192.4
1965	8.1	67.3	10.2	42.0	8.9	2.0	138.5	70.6	209.1
1966	7.9	72.6	11.2	40.5	8.5	1.9	142.6	68.2	210.7
1967	8.2	60.8	11.4	40.6	8.7	1.6	131.3	68.8	200.1
1968	9.0	65.9	12.7	40.4	8.7	1.5	138.3	70.8	209.1
1969	10.4	72.4	14.8	42.9	7.9	2.2	150.7	75.7	226.5
1970	11.3	78.0	14.9	44.2	9.3	2.0	159.7	69.6	229.3
1971	10.7	83.0	14.9	45.1	9.3	1.9	164.9	68.4	233.3
1972	12.5	79.0	16.6	54.2	9.5	1.8	173.6	70.8	244.4
1973	13.8	78.0	18.4	57.8	9.1	2.0	179.1	76.1	255.2
1974	14.5	65.0	16.9	55.6	8.8	2.3	163.2	75.8	239.0
1975	13.6	57.0	16.6	45.6	9.1	2.2	144.1	73.5	217.6
1976	14.1	55.1	19.0	44.9	10.5	1.8	145.5	80.3	225.8
1977	15.5	50.1	19.0	45.2	10.0	1.9	141.7	80.5	222.2
1978	15.3	53.0	21.2	49.2	10.4	2.2	151.3	92.1	243.4
1979	16.2	60.1	21.7	56.7	11.0	2.6	168.3	92.8	261.1
1980	18.6	62.8	22.4	45.5	10.4	3.3	163.0	96.6	259.7
1981	18.2	64.8	18.9	43.4	9.4	2.9	157.7	77.1	234.8
1982	19.2	69.6	18.6	42.1	11.0	3.1	163.6	82.3	246.0
1983	21.2	82.4	19.1	41.3	12.3	2.8	179.0	83.9	262.9
1984	21.9	80.2	20.0	43.3	11.8	3.4	180.6	91.9	272.5
1985	21.4	85.2	22.1	44.0	11.6	3.5	187.8	99.5	287.3
1986	19.3	86.8	21.9	39.5	12.0	3.5	183.0	93.4	276.5
1987	19.2	97.1	23.2	43.0	8.0	3.8	194.3	95.8	290.1
1988	20.1	92.0	22.9	45.5	10.2	3.8	194.4	99.8	294.3
1989	19.8	97.4	22.9	47.0	11.7	4.4	203.2	102.1	305.3
1990	19.7	93.4	23.4	44.0	12.0	4.2	196.7	98.9	295.6
1991	18.1	83.4	23.9	36.0	11.1	4.0	176.5	93.3	269.8
1992	17.3	77.4	22.8	41.7	10.1	4.3	173.6	90.5	264.1
1993	17.8	66.4	23.2	43.7	11.7	4.5	167.4	99.0	266.4
1994	17.9	69.4	25.8	50.9	10.9	5.2	180.1	114.2	294.3
1995	16.0	66.4	24.5	54.4	12.4	4.6	178.2	112.1	290.3

APPENDIX 5. **Cont.**

	Ores	**Stone Mate-rial*)**	**Fossil fuels and peat**	**Wood mate-rial**	**Crops**	**Others**	**DMF**	**Hidden flows*)**	**TMF**
1996	16.4	66.4	27.8	48.9	12.4	4.8	176.7	119.1	295.9
1997	17.2	70.4	26.0	53.9	12.9	5.6	185.9	116.1	302.0
1998	17.3	75.4	25.2	57.9	12.0	5.8	193.6	113.1	306.8
1999	17.6	80.4	23.7	59.3	12.6	5.5	199.0	115.5	314.5
2000	17.4	80.4	22.1	59.9	14.0	5.8	199.6	131.9	331.5

*) = 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. coke and peat extraction. **Timber:** quantity of domestic net fellings and imported timber. **Crops:** quantity of field crops. other cultivated plants and garden production. **Others:** imports of metals. forestry by-products and fishing catches.

*Sources: **Ores:** Mining Industry Association. **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 records. **Timber resources and forestry by-products:** Finnish Statistical Yearbooks of Forestry (e.g. see FFRI 2000). **Peat:** Peat Industry Association and Finnish Statistical Yearbooks of Forestry (e.g. see FFRI 2000). **Crops:** Statistical Yearbooks of Agriculture. (e.g. see MoAF 2000). **Others:** Research Publications of the Institute of Fisheries and Game.*

NB. Sources are mostly statistical records maintained by above mentioned agencies and some of them are unpublished.

APPENDIX 6.
Finland's environmental protection costs and revenue of environmental taxes (FIM million)

	Environmental protection expenditure						Environment related taxes and fees			
	State	Trans-fers	Munici-palities	Indus-try	NGO's	Total, cp	Total, rp	Reve-nue, cp	Reve-nue, rp	Share of total tax rev-enue
1960	6	0	168	48	0	**222**	2,577	140	**1,619**	6.0%
1961	8	0	204	66	0	**278**	3,063	145	**1,595**	5.5%
1962	8	0	240	73	0	**321**	3,402	179	**1,900**	5.8%
1963	11	0	276	79	0	**366**	3,689	268	**2,703**	8.5%
1964	11	0	297	83	0	**391**	3,677	351	**3,296**	7.6%
1965	14	0	318	87	0	**419**	3,752	554	**4,957**	10.9%
1966	15	–1	342	102	0	**458**	3,933	665	**5,682**	11.7%
1967	27	–11	363	106	0	**485**	4,037	712	**5,671**	10.9%
1968	37	–18	384	110	0	**513**	3,902	719	**5,110**	10.3%
1969	20	–1	405	114	0	**538**	3,685	918	**6,267**	10.8%
1970	26	–1	451	160	0	**636**	4,192	1,008	**6,622**	10.7%
1971	34	–2	486	389	0	**907**	5,562	1,079	**6,587**	10.4%
1972	55	–14	526	423	0	**990**	5,735	1,261	**7,105**	10.2%
1973	65	–9	659	517	1	**1,233**	6,178	1,538	**7,593**	10.2%
1974	85	–26	804	654	1	**1,518**	6,330	1,605	**6,470**	8.7%
1975	112	–37	882	783	1	**1,741**	6,131	2,069	**7,286**	9.6%
1976	124	–37	912	619	1	**1,619**	5,034	3,136	**9,753**	11.2%
1977	137	–38	941	676	2	**1,718**	4,869	3,435	**9,735**	11.6%
1978	137	–39	990	674	2	**1,764**	4,643	3,695	**9,726**	11.4%
1979	119	–19	1,028	682	2	**1,812**	4,379	4,296	**10,381**	12.3%
1980	160	–37	1,170	848	3	**2,144**	4,722	5,130	**11,298**	13.0%
1981	194	–42	1,232	928	5	**2,317**	4,599	5,755	**11,423**	12.3%
1982	225	–53	1,302	1,165	5	**2,644**	4,815	6,608	**12,035**	12.7%
1983	251	–53	1,258	1,204	8	**2,668**	4,482	7,061	**11,861**	12.5%
1984	304	–57	1,438	1,264	8	**2,957**	4,580	8,103	**12,551**	12.3%
1985	399	–60	1,562	1,719	8	**3,628**	5,327	9,021	**13,245**	12.2%
1986	435	–53	1,719	1,323	9	**3,433**	4,833	9,180	**12,924**	11.5%
1987	536	–50	1,711	1,666	8	**3,871**	5,228	7,932	**10,712**	9.1%
1988	480	–28	2,625	1,735	8	**4,820**	6,021	9,653	**12,059**	9.5%
1989	684	–53	2,937	2,630	7	**6,205**	7,304	10,840	**12,760**	9.3%
1990	639	–31	2,409	3,008	7	**6,032**	6,735	10,992	**12,272**	9.1%
1991	929	–72	3,610	2,724	11	**7,202**	7,895	10,193	**11,174**	8.8%
1992	1,694	–33	3,549	3,195	14	**8,419**	9,151	10,560	**11,477**	10.0%
1993	1,688	–50	3,500	3,124	14	**8,276**	8,789	12,279	**13,040**	12.3%

	Environmental protection expenditure						Environment related taxes and fees			
	State	**Trans-fers**	**Munici-palities**	**Indus-try**	**NGO's**	**Total, cp**	**Total, rp**	**Reve-nue, cp**	**Reve-nue, rp**	**Share of total tax rev-enue**
1994	1,968	–66	3,147	2,512	14	**7,575**	7,887	13,855	**14,427**	13.3%
1995	3,426	–31	3,234	3,113	15	**9,757**	9,757	16,194	**16,194**	15.3%
1996	3,791	–63	3,206	3,415	15	**10,364**	10,388	18,524	**18,566**	14.9%
1997	4,223	–80	3,284	3,327	15	**10,769**	10,576	20,469	**20,102**	15.3%
1998	4,491	–59	2,998	3,172	15	**10,617**	10,123	23,122	**22,046**	16.6%
1999	4,362	–55	3,183	3,172*)	15	**10,677**	10,192	24,576	**23,459**	16.1%
2000	4,151	–37	3,290*)	3,172*)	13	**10,589**	9,777	24,453	**22,578**	14.7%
2001	4,239	–50	..	..	..	**..**	..	23,676	**21,861**	13.4%

cp = current prices. rp = real prices. .. = no data available. *) = forecast.

NB1. Except for state environmental protection expenditures, transfers and environment related taxes, the data concerning years 1960–1989 have largely been imputed according to information available and are thus the best estimates available. Classification: **State:** environmental administration, environmental co-operation in Central and Eastern Europe, environmental protection and nature conservation, environmental research, environmental costs in agri-culture and energy saving costs. Transfers comprise various transfers of funds such as grants and subsidies to municipali-ties 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:** all industrial envi-ronmental protection costs. **NGO's:** Salary costs of environmental organisations.

NB2. FIM 1 = 0.168188 EUR and EUR 1 = FIM 5.945730 & FIM 1 = 0.154127 USD and USD 1 = FIM 6.488138 (25 Sep 2001).

Sources: Government budget proposals 1960-2002; Hoffrén 1997a, 129; Hoffrén 1999, 9, 12 and Hoffrén 2001, 11, 13.

APPENDIX 7.
Progress of GDP, GNP, EDP1 and EDP2 Finland in 1960–2000 (FIM million)

	GDP, cp	GDP, rp	GNP, cp	GNP, rp	EDP1, cp	EDP1, rp	EDP2, cp	EDP2, rp
1960	16,199	188,034	16,172	187,720	13,997	162,474	13,321	154,624
1961	18,362	202,334	18,320	201,871	15,761	173,673	14,960	164,852
1962	19,661	208,367	19,597	207,689	16,860	178,682	16,012	169,690
1963	21,352	215,212	21,260	214,284	18,287	184,319	17,340	174,775
1964	24,083	226,486	23,960	225,330	20,732	194,972	19,687	185,148
1965	26,634	238,497	26,483	237,145	23,057	206,466	21,930	196,374
1966	28,554	244,155	28,381	242,676	24,653	210,799	23,453	200,540
1967	31,321	249,450	31,085	247,571	26,972	214,814	25,614	203,995
1968	35,908	255,196	35,601	253,014	30,836	219,150	29,169	207,302
1969	40,986	279,678	40,617	277,160	35,409	241,622	33,553	228,954
1970	45,743	300,571	45,317	297,772	39,220	257,709	37,196	244,407
1971	50,257	306,850	49,761	303,821	42,544	259,757	40,415	246,757
1972	58,625	330,266	57,977	326,616	49,581	279,317	47,153	265,640
1973	71,364	352,419	70,549	348,394	60,217	297,371	57,220	282,573
1974	90,055	363,092	89,013	358,890	75,652	305,020	72,199	291,098
1975	106,077	373,569	104,715	368,773	88,224	310,697	84,360	297,089
1976	120,019	373,202	118,347	368,003	99,606	309,727	94,856	294,956
1977	132,138	374,461	129,872	368,040	107,616	304,969	102,343	290,027
1978	145,593	383,194	143,132	376,717	118,238	311,197	112,255	295,449
1979	169,295	409,122	166,783	403,051	138,292	334,200	131,623	318,083
1980	195,287	430,063	192,361	423,619	159,031	350,220	151,727	334,136
1981	221,310	439,265	216,863	430,438	179,283	355,848	172,100	341,592
1982	248,773	453,047	243,047	442,619	201,242	366,487	193,751	352,844
1983	277,080	465,470	270,690	454,735	224,096	376,462	216,200	363,197
1984	310,786	481,384	304,189	471,166	252,297	390,789	243,669	377,425
1985	338,037	496,326	331,736	487,075	275,165	404,014	265,627	390,010
1986	361,326	508,687	354,803	499,504	294,,540	414,663	284,458	400,470
1987	392,518	530,133	385,599	520,788	318782	430,546	308,649	416,861
1988	444,482	555,231	437,309	546,271	361,815	451,966	350,148	437,392
1989	495,957	583,768	484,461	570,237	397,517	467,899	385,582	453,850
1990	523,034	583,954	508,842	568,109	412,587	460,643	400,511	447,170
1991	499,357	547,419	480,502	526,749	380,680	417,320	368,613	403,974
1992	486,923	529,235	462,734	502,944	359,726	390,985	348,186	378,566
1993	492,609	523,157	464,527	493,334	360,033	382,360	348,906	370,549
1994	522,309	543,846	499,551	520,150	393,937	410,181	381,318	397,049
1995	564,566	564,566	543,934	543,934	433,535	433,535	420,906	420,915
1996	585,865	587,202	568,965	570,263	457,592	458,636	444,147	445,168
1997	635,532	624,147	622,832	611,675	506,682	497,605	493,050	484,218
1998	689,523	657,445	672,694	641,399	551,210	525,567	537,668	512,475
1999	716,404	683,853	702,619	670,694	576,111	549,934	562,569	536,967
2000	782,876	722,860	769,509	710,518	635,301	586,598	621,759	573,628

cp = current prices.   rp = real prices.

NB. FIM 1 = 0.168188 EUR and EUR 1 = FIM 5.945730 & FIM 1 = 0.154127 USD and
USD 1 = FIM 6.488138 (25 Sep 2001).

APPENDIX 8.
Components of Finnish EDP calculations (FIM million, real prices)

	GDP incomes from ROW	**Factor**	**GNP**	**Consumpti-on of fixed capital**	**NNI**
1960	188,034	–313	187,720	–21,405	166,316
1961	202,334	–463	201,871	–23,195	178,676
1962	208,367	–678	207,689	–24,556	183,133
1963	215,212	–927	214,284	–25,631	188,653
1964	226,486	–1,157	225,330	–26,248	199,082
1965	238,497	–1,352	237,145	–27,347	209,797
1966	244,155	–1,479	242,676	–28,790	213,886
1967	249,450	–1,880	247,571	–29,715	217,856
1968	255,196	–2,182	253,014	–30,986	222,028
1969	279,678	–2,518	277,160	–32,502	244,659
1970	300,571	–2,799	297,772	–36,212	261,560
1971	306,850	–3,028	303,821	–39,332	264,489
1972	330,266	–3,651	326,616	–42,516	284,099
1973	352,419	–4,025	348,394	–46,015	302,379
1974	363,092	–4,201	358,890	–49,499	309,391
1975	373,569	–4,797	368,772	–56,347	312,426
1976	373,202	–5,199	368,003	–57,850	310,153
1977	374,461	–6,422	368,039	–61,274	306,766
1978	383,194	–6,477	376,717	–63,388	313,329
1979	409,122	–6,071	403,051	–65,621	337,430
1980	430,063	–6,444	423,619	–70,317	353,303
1981	439,265	–8,827	430,438	–72,292	358,147
1982	453,047	–10,428	442,619	–73,974	368,645
1983	465,470	–10,735	454,735	–76,607	378,128
1984	481,384	–10,218	471,166	–78,374	392,792
1985	496,326	–9,252	487,074	–81,359	405,715
1986	508,687	–9,183	499,504	–84,087	415,417
1987	530,133	–9,345	520,788	–88,509	432,280
1988	555,231	–8,960	546,271	–91,496	454,774
1989	583,768	–13,531	570,237	–97,761	472,475
1990	583,954	–15,845	568,109	–103,723	464,386
1991	547,419	–20,670	526,749	–105,468	421,281
1992	529,235	–26,291	502,944	–104,536	398,409
1993	523,157	–29,823	493,334	–104,195	389,138
1994	543,846	–23,696	520,150	–104,445	415,704
1995	564,566	–20,632	543,934	–102,137	441,797
1996	587,202	–16,939	570,263	–103,300	466,963
1997	624,147	–12,472	611,675	–104,382	507,293
1998	657,445	–16,046	641,399	–106,462	534,937
1999	683,853	–13,159	670,694	–111,266	559,429
2000	722,860	–12,342	710,518	–114,514	596,003

NB. FIM 1 = 0.168188 EUR and EUR 1 = FIM 5.945730 & FIM 1 = 0.154127 USD and USD 1 = FIM 6.488138 (FIM/USD rate on 25 Sep 2001).

Source: *These aggregate measures are directly diverted from Finnish National Accounts (Official SNA) produced by Statistics Finland.*

APPENDIX 8. Cont.

	NNI	A.1 Net growth of Forests	B1. State	B1B. Trans-fers	B2. Local govern-ments	B3. In-dustry	B4. Env. NGO's	Env. expen-diture, total	EDP1
1960	166,316	–1,150	70	0	1,950	557	0	2,577	162,473
1961	178,676	–1,763	88	0	2,248	727	0	3,063	173,673
1962	183,133	–954	85	0	2,544	774	0	3,402	178,682
1963	188,653	–587	111	0	2,782	796	0	3,689	184,319
1964	199,082	–393	103	0	2,793	781	0	3,677	194,972
1965	209,797	383	125	0	2,848	779	0	3,752	206,466
1966	213,886	770	128	9	2,924	872	0	3,933	210,799
1967	217,856	905	215	–88	2,891	844	0	4,038	214,814
1968	222,028	930	263	–128	2,729	782	0	3,902	219,150
1969	244,659	589	136	–7	2,764	778	0	3,685	241,622
1970	261,560	311	171	–7	2,963	1,051	0	4,192	257,709
1971	264,489	755	208	–12	2,967	2,375	0	5,562	259,757
1972	284,099	866	310	–79	2,963	2,383	0	5,735	279,317
1973	302,379	1,064	321	–44	3,254	2,553	5	6,178	297,371
1974	309,391	1,782	343	–105	3,242	2,637	4	6,330	305,020
1975	312,426	4,402	394	–130	3,106	2,757	4	6,131	310,696
1976	310,153	4,608	386	–115	2,836	1,925	3	5,034	309,727
1977	306,766	3,072	388	–108	2,667	1,916	6	4,869	304,969
1978	313,329	2,511	361	–103	2,606	1,774	5	4,643	311,197
1979	337,430	1,148	288	–46	2,484	1,648	5	4,379	334,199
1980	353,303	1,638	352	–81	2,577	1,867	7	4,722	350,220
1981	358,147	2,300	385	–83	2,445	1,842	10	4,599	355,848
1982	368,645	2,657	410	–97	2,371	2,122	9	4,815	366,487
1983	378,128	2,816	422	–89	2,113	2,023	13	4,482	376,462
1984	392,792	2,577	471	–88	2,227	1,958	12	4,580	390,789
1985	405,715	3,625	586	–88	2,293	2,524	12	5,327	404,014
1986	415,417	4,080	612	–75	2,420	1,863	13	4,833	414,663
1987	432,280	3,494	724	–68	2,311	2,250	11	5,228	430,545
1988	454,774	3,213	600	–35	3,279	2,167	10	6,021	451,966
1989	472,475	2,727	805	–62	3,457	3,096	8	7,304	467,899
1990	464,386	2,991	713	–35	2,690	3,358	8	6,735	460,643
1991	421,281	3,933	1,018	–79	3,957	2,986	12	7,895	417,320
1992	398,409	1,727	1,841	–36	3,857	3,473	15	9,151	390,985
1993	389,138	2,010	1,793	–53	3,717	3,318	15	8,789	382,360
1994	415,704	2,364	2,049	–69	3,277	2,616	15	7,887	410,181
1995	441,797	1,495	3,426	–31	3,234	3,113	15	9,757	433,535
1996	466,963	2,061	3,800	–63	3,213	3,423	15	10,388	458,636
1997	507,293	889	4,147	–79	3,225	3,267	15	10,576	497,605
1998	534,937	752	4,282	–56	2,859	3,024	14	10,123	525,567
1999	559,429	698	4,164	–53	3,038	3,028	14	10,192	549,934
2000	596,003	372	3,833	–34	3,038	2,929	12	9,777	586,598

NB3. In order to calculate Finnish EDP1 figures net growth of forest (production of natural assets) in economic use (pro-tected forests are excluded) have been added and environmental expenditures (so-ciety's protection expenditures) have been subracted from NNI measure. **A.1 Net Growth of Forests:** Value of net growth is imputed on the basis of forest growth information (average annual growth of each roundwood assortment) times yearly average stumpage prices for each roundwood assortment. As sources Statistical Yearbooks of Forestry (Finnish Forest Research Institute) and Natural Resources Accounts of Statistics Finland have been utilised. **B.1 State:** environmental administration, environ-mental co-operation in Central and Eastern Europe, environmental protection and nature conservation, environmental research, envi-ronmental costs in agriculture and energy saving costs. **B.1B Transfers** comprise various transfers of funds such as grants and subsidies to municipalities and enterprises. **B.2 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. **B.3 Industry:** all industrial environmental protection costs. **B.4 NGO's:** Salary costs of environmental or-ganisa-tions. Sources of Environmental expenditures: Except for state environmental protection expen-ditures, transfers and envi-ronment related taxes, the dataconcerning years 1960–1989 have largely been imputed according to information available and are thus the best estimates available.

APPENDIX 8. Cont.

	EDP1	C.1 Green house effect	C.2 Binding of carbon	C.3 Acid deposition	C.4 Defo-liation	Changes in env. as-sets, total	EDP 2
1960	162,473	–2,210	–624	–4,950	–66	–7,850	154,623
1961	173,673	–2,720	–859	–5,170	–72	–8,821	164,852
1962	178,682	–3,060	–516	–5,346	–70	–8,992	169,690
1963	184,319	–3,570	–328	–5,566	–80	–9,544	174,775
1964	194,972	–3,740	–256	–5,742	–86	–9,824	185,148
1965	206,466	–4,080	26	–5,962	–76	–10,092	196,374
1966	210,799	–4,250	244	–6,182	–71	–10,259	200,540
1967	214,814	–4,760	366	–6,358	–67	–10,819	203,995
1968	219,150	–5,610	411	–6,578	–71	–11,848	207,302
1969	241,622	–5,950	125	–6,754	–89	–12,668	228,954
1970	257,709	–6,120	–127	–6,974	–81	–13,302	244,407
1971	259,757	–5,950	33	–6,996	–87	–13,000	246,757
1972	279,317	–6,630	46	–6,996	–97	–13,677	265,640
1973	297,371	–7,650	60	–7,040	–168	–14,798	282,573
1974	305,020	–6,800	190	–7,062	–250	–13,922	291,098
1975	310,696	–6,970	657	–7,084	–211	–13,608	297,089
1976	309,727	–8,160	723	–7,084	–250	–14,771	294,956
1977	304,969	–8,330	701	–7,106	–207	–14,942	290,027
1978	311,197	–9,010	614	–7,150	–202	–15,748	295,449
1979	334,199	–9,010	304	–7,150	–260	–16,116	318,083
1980	350,220	–9,180	562	–7,172	–294	–16,084	334,136
1981	355,848	–7,599	641	–6,974	–325	–14,256	341,592
1982	366,487	–7,276	757	–6,798	–326	–13,643	352,844
1983	376,462	–7,208	844	–6,578	–323	–13,265	363,197
1984	390,789	–7,378	772	–6,402	–356	–13,364	377,425
1985	404,014	–8,415	1,022	–6,204	–407	–14,004	390,010
1986	414,663	–8,177	1,222	–6,842	–397	–14,194	400,469
1987	430,545	–8,823	1,057	–5,500	–419	–13,685	416,861
1988	451,966	–8,772	949	–6,270	–481	–14,574	437,392
1989	467,899	–8,823	816	–5,544	–497	–14,048	453,850
1990	460,643	–9,027	883	–4,818	–511	–13,473	447,170
1991	417,320	–9,044	1,264	–4,950	–616	–13,346	403,974
1992	390,985	–8,738	1,035	–4,312	–404	–12,419	378,566
1993	382,360	–8,840	938	–3,564	–345	–11,811	370,549
1994	410,181	–9,911	711	–3,520	–411	–13,131	397,049
1995	433,535	–9,384	641	–3,410	–467	–12,620	420,915
1996	458,636	–10,472	807	–3,322	–481	–13,468	445,168
1997	497,605	–10,166	502	–3,212	–511	–13,387	484,218
1998	525,567	–9,758	452	–3,256	–529	–13,091	512,475
1999	549,934	–9,602	457	–3,284	–539	–12,968	536,967
2000	586,598	–9,532	384	–3,260	–561	–12,970	573,628

NB4. In order to calculate Finnish EDP2 measures Changes in environmental assets have been have been subracted from EDP1 measure. **C.1 Greenhouse effect:** Value of Finland's emissions of carbon dioxide or contribution to global greenhouse effect has been estimated on the basis of emission data (for data see Appendix 1). **C.2 Carbon binding of forests** is estimated on the basis of net growth of forests in economic use. **C.3 Acid deposition:** Value of "landfill service" of Fin-nish ecosystems has been estimated on the basis of yearly acid defoliation of Finland (see data in Statistical Appendix 2). **C.4 Defoliation** (of forests) is estimated on the basis of roundwood net growth loss (for each roundwood assortment) due to defoliation (over 41 per cent defoliation). Prices used : C.1 and C.2 : FIM 150 per tonne, C.3: FIM 20,000 per tonne and C.4 yearly average stumpage prices for each roundwood assortment.

APPENDIX 9.
Progress of Finnish GDP, EDP1, EDP2 and ISEW per capita (FIM, rp) and progress of Human Development Index in Finland

	GDP per capita	GNP per capita	EDP1 per capita	EDP2 per capita	ISEW per capita	Human Development Index HDI
1960	42,449	42,378	36,679	34,907	14,275	0,785
1961	45,356	45,252	38,931	36,954	14,172	0,789
1962	46,392	46,241	39,783	37,781	13,417	0,794
1963	47,578	47,373	40,749	38,639	13,368	0,798
1964	49,793	49,539	42,865	40,705	14,321	0,802
1965	52,259	51,963	45,241	43,029	13,852	0,807
1966	53,299	52,976	46,017	43,778	14,022	0,811
1967	54,161	53,753	46,640	44,291	15,769	0,815
1968	55,160	54,688	47,369	44,808	14,714	0,820
1969	60,487	59,942	52,256	49,517	20,290	0,824
1970	65,252	64,644	55,947	53,059	24,523	0,828
1971	66,531	65,874	56,320	53,502	17,099	0,829
1972	71,183	70,397	60,202	57,254	34,139	0,829
1973	75,528	74,665	63,730	60,559	46,010	0,830
1974	77,409	76,513	65,028	62,060	53,970	0,831
1975	79,290	78,272	65,945	63,057	43,352	0,835
1976	78,973	77,873	65,542	62,416	46,300	0,839
1977	79,019	77,663	64,354	61,201	54,900	0,843
1978	80,630	79,267	65,480	62,167	56,383	0,847
1979	85,865	84,591	70,141	66,758	57,722	0,851
1980	89,980	88,632	73,275	69,910	61,231	0,854
1981	91,514	89,675	74,136	71,165	65,841	0,857
1982	93,858	91,698	75,925	73,099	70,967	0,861
1983	95,859	93,648	77,528	74,797	71,740	0,864
1984	98,608	96,515	80,050	77,313	50,175	0,868
1985	101,245	99,358	82,415	79,558	53,111	0,872
1986	103,431	101,563	84,313	81,427	32,558	0,877
1987	107,486	105,591	87,294	84,520	34,711	0,881
1988	112,248	110,436	91,371	88,425	29,081	0,886
1989	117,592	114,866	94,251	91,422	31,854	0,890
1990	117,109	113,931	92,379	89,677	27,495	0,894
1991	109,184	105,061	83,235	80,573	44,238	0,897
1992	104,966	99,751	77,546	75,083	42,493	0,897
1993	103,259	97,373	75,469	73,138	34,899	0,898
1994	106,881	102,224	80,612	78,031	34,956	0,903
1995	110,530	106,491	84,877	82,407	30,809	0,907
1996	114,586	111,280	89,497	86,869	38,058	0,909
1997	121,433	119,007	96,813	94,209	33,264	0,913
1998	127,573	124,459	101,983	99,442	32,656	0,917
1999	132,697	130,144	106,711	104,195	31,510	0,925
2000	140,266	137,871	113,825	111,308	29,284	..

rp = real prices; here at 1995 price level. .. = data not available.
NB. FIM 1 = 0.168188 EUR and EUR 1 = FIM 5.945730 & FIM 1 = 0.154127 USD and USD 1 = FIM 6.488138 (25 Sep 2001).

*Sources : **GDP and GNP:** Statistics Finland; **EDP1** and **EDP2:** Hoffren 1999b; **ISEW:** see Appendix 10; HDI: UNDP 2001, p. 145; UNDP 2000, p. 157; UNDP 1999, p 151, 164; UNDP 1998 p. 140; UNDP 1996, p. 135; UNDP 1995, p. 155; UNDP 1994, p. 105; UNDP 1993, p. 135 and UNDP 1990, p. 111.*

APPENDIX 10.
Components of Finnish ISEW (FIM billion)

Year	Per-sonal Con-sump-tion	Distri-bution al In-equal-ity	Weighted personal con-sump-tion	Ser-vices: House-hold labour	Ser-vices: Con-sumer durable s	Ser-vices: Streets and High-ways	Public expendit ures on health and ed-ucation	Expen-ditures on con-sumer durable s	Defen-sive pri-vate ex-penditu res health and ed-ucation
A	**B**	**C**	**D**	**E (+)**	**F (+)**	**G (+)**	**H (+)**	**I (-)**	**J (-)**
1960	136.8	99.4	137.7	39.4	2.6	0.2	2.0	7.5	0.0
1961	143.9	100.0	143.9	39.2	3.1	0.2	2.2	8.7	0.1
1962	153.6	105.0	146.3	39.6	3.7	0.2	2.5	10.3	0.1
1963	161.8	106.0	152.7	41.8	4.2	0.2	2.8	10.5	0.2
1964	171.8	110.6	155.3	44.8	4.7	0.2	3.2	12.1	-0.2
1965	180.6	112.6	160.4	49.7	5.3	0.3	4.0	13.5	0.3
1966	185.3	114.8	161.4	53.0	5.7	0.3	4.4	12.0	0.3
1967	189.6	108.0	175.6	53.4	5.9	0.4	5.5	11.8	0.3
1968	187.7	101.6	184.7	51.3	5.7	0.4	5.9	10.6	0.4
1969	202.1	95.7	211.1	54.7	6.2	0.4	6.6	14.2	0.4
1970	213.6	90.2	237.0	50.1	6.8	0.5	7.1	16.0	0.5
1971	218.2	101.6	214.6	55.3	7.0	0.5	7.4	14.8	0.4
1972	236.6	76.4	309.8	60.6	7.6	0.6	8.2	18.9	0.9
1973	246.7	68.9	357.9	68.5	8.0	0.6	8.9	21.4	0.7
1974	248.0	62.4	397.4	64.2	7.7	0.6	9.2	19.6	0.6
1975	199.9	56.6	353.5	69.1	8.3	0.9	10.4	24.0	0.7
1976	202.4	51.3	394.7	72.6	8.7	0.9	10.8	22.0	0.8
1977	203.9	46.5	438.7	73.1	9.2	0.9	11.1	20.9	0.8
1978	209.1	46.6	449.1	76.6	9.7	0.9	11.1	21.3	1.0
1979	218.6	48.1	454.3	74.9	10.3	0.9	11.4	24.6	1.0
1980	226.2	47.0	481.4	75.7	10.8	1.0	12.0	25.0	1.0
1981	230.4	47.1	489.6	75.6	11.1	1.0	12.6	25.2	1.0
1982	242.0	47.1	513.2	73.6	11.8	0.9	13.3	27.5	1.1
1983	248.5	46.7	531.5	69.8	12.4	0.9	13.8	28.2	1.4
1984	252.6	56.5	447.3	70.5	12.9	0.9	14.2	28.9	1.6
1985	262.3	58.2	450.5	76.3	13.9	0.8	15.4	31.2	1.9
1986	268.9	63.1	425.8	74.4	15.0	0.8	16.2	32.8	1.9
1987	279.7	63.4	441.5	74.9	16.2	0.8	17.2	35.6	2.0
1988	285.4	65.5	436.0	72.5	17.0	0.8	17.6	39.0	2.1
1989	296.1	65.3	453.1	71.4	18.1	0.8	18.9	40.0	2.2
1990	294.3	65.2	451.2	70.7	18.6	0.8	20.6	35.2	2.4
1991	294.3	64.4	456.9	72.3	18.7	0.8	22.6	27.9	2.6
1992	290.6	64.0	454.1	74.5	18.4	0.7	22.0	22.8	2.9
1993	285.8	65.9	433.9	75.6	17.5	0.6	19.3	20.9	3.2
1994	290.2	65.8	440.8	76.9	16.9	0.5	18.1	23.4	3.2
1995	292.1	67.5	432.6	76.5	16.2	0.6	18.4	25.5	3.2
1996	309.2	67.1	460.9	79.3	16.6	0.6	19.6	28.9	3.4
1997	317.8	69.7	455.9	80.3	16.7	0.6	20.4	30.1	3.5
1998	329.9	72.3	456.4	80.5	17.0	0.7	20.7	33.9	3.4
1999	347.1	76.5	453.5	83.1	18.0	0.7	21.1	35.8	3.7
2000	358.0	76.5	467.8	82.8	18.5	0.6	20.5	36.3	3.5

NB. FIM 1 = 0.168188 EUR and EUR 1 = FIM 5.945730 & FIM 1 = 0.154127 USD and USD 1 = FIM 6.488138 (25 Sep 2001).

APPENDIX 10. **Cont.**

Year	Expendi tu-res on na-tional adver-ti sing	Costs of commu-ting	Cost of ur-bani sation	Cost of auto acci-den ts	Costs of water pollu-tion	Costs of air polluti-on	Costs of noise pollu-tion	Loss of wetland s	Loss of farm-land
A	**K (-)**	**L (-)**	**M (-)**	**N (-)**	**O (-)**	**P (-)**	**Q (-)**	**R (-)**	**S (-)**
1960	1.1	4.2	3.4	1.1	19.1	14.1	0.2	11.2	2.9
1961	1.2	4.5	3.5	1.2	19.8	16.1	0.2	11.6	3.2
1962	1.3	4.6	3.6	1.2	19.7	17.9	0.3	12.1	3.4
1963	1.4	4.8	3.8	1.5	20.1	19.9	0.3	12.6	3.5
1964	1.4	5.0	3.9	1.6	21.5	21.6	0.3	13.3	3.8
1965	1.5	5.4	4.0	1.9	21.9	23.2	0.4	14.1	4.0
1966	1.5	5.5	4.1	2.1	21.9	24.5	0.4	15.0	4.2
1967	1.5	5.6	4.3	2.0	21.8	26.4	0.4	16.2	4.5
1968	1.4	5.7	4.3	2.2	22.2	28.5	0.5	17.6	5.0
1969	1.5	6.3	4.5	2.4	22.6	30.1	0.5	19.0	5.2
1970	1.5	6.8	4.6	2.6	22.9	30.5	0.5	20.6	5.4
1971	2.2	6.7	4.9	3.0	22.3	30.6	0.5	22.0	15.6
1972	2.8	7.1	5.2	3.3	22.3	31.8	0.6	23.3	16.9
1973	2.8	7.4	5.5	3.5	21.8	31.2	0.6	24.9	19.2
1974	2.2	7.4	5.9	3.4	21.3	27.9	0.6	26.5	23.6
1975	2.4	7.4	6.1	4.1	20.3	25.8	0.7	28.5	27.0
1976	3.0	7.6	6.4	4.2	19.1	25.0	0.7	30.5	30.5
1977	3.2	7.8	6.7	4.1	18.0	23.1	0.7	32.5	33.5
1978	3.6	8.2	6.9	3.8	16.4	24.9	0.7	34.4	36.1
1979	4.0	8.9	7.2	4.4	15.9	25.0	0.7	36.1	39.3
1980	4.4	9.6	7.5	4.1	16.1	25.3	0.9	37.9	43.1
1981	4.8	9.8	7.6	4.7	16.5	22.5	0.9	39.6	4.9
1982	5.1	10.1	7.7	5.2	16.6	21.1	0.9	41.2	5.3
1983	5.7	10.4	7.8	5.9	16.3	19.6	0.9	42.9	5.7
1984	6.1	10.7	7.8	5.8	16.9	19.0	1.0	44.7	6.2
1985	6.5	11.0	7.9	6.2	17.1	20.8	1.0	46.3	6.6
1986	6.8	11.3	8.1	7.3	16.9	20.2	1.1	48.0	64.2
1987	7.1	11.8	8.4	7.3	17.4	20.6	1.2	49.5	67.0
1988	7.4	12.4	8.6	8.8	17.7	20.4	1.2	51.4	72.4
1989	6.9	12.8	8.9	10.4	17.9	20.2	1.3	53.0	76.8
1990	6.7	13.2	9.2	9.8	17.8	20.4	1.4	54.3	81.0
1991	5.9	12.2	9.4	9.7	17.3	19.7	1.5	55.4	9.4
1992	5.9	11.5	9.6	9.3	17.1	19.3	1.5	56.5	9.4
1993	5.9	10.9	9.7	7.7	16.9	18.9	1.5	57.4	9.7
1994	6.3	10.5	9.8	7.8	17.1	19.6	1.5	57.9	9.8
1995	6.6	10.0	9.8	7.5	17.1	18.3	1.5	58.4	10.3
1996	6.7	11.1	9.9	6.9	17.2	19.7	1.5	58.7	10.2
1997	7.1	11.8	10.0	7.6	17.3	19.2	1.5	58.9	10.4
1998	8.2	13.6	10.1	7.0	17.3	19.1	1.5	59.1	10.8
1999	8.6	14.1	10.2	7.4	17.1	18.9	1.5	59.2	10.7
2000	8.3	14.9	9.8	7.4	17.1	18.3	1.5	59.3	11.1

NB. FIM 1 = 0.168188 EUR and EUR 1 = FIM 5.945730 & FIM 1 = 0.154127 USD and USD 1 = FIM 6.488138 (25 Sep 2001).

APPENDIX 10. Cont.

Year	Deple-tion of non-re-newable resour-ces	Longterm environ-mental damage	Net capital growt h	Change in net interna-tional position	Index of sustain-able eco-nomic welfare ISEW	Per capita ISEW	Gross National Product	Per capita GNP
A	T (-)	U (-)	V (+)	W (+)	X (sum)	Y	Z	AA
1960	2.3	51.7	0.0	0.0	63.2	14,274.8	187.7	42,378.3
1961	2.4	53.7	0.0	0.9	63.2	14,172.3	201.9	45,252.4
1962	2.2	55.9	0.0	0.6	60.3	13,416.7	207.7	46,241.0
1963	2.3	58.2	0.0	–2.3	60.5	13,368.2	214.3	47,373.4
1964	2.8	60.6	0.0	4.7	65.1	14,320.7	225.3	49,538.8
1965	3.2	63.2	0.0	0.0	63.2	13,852.2	237.1	51,962.9
1966	3.1	66.0	0.0	0.0	64.2	14,021.6	242.7	52,976.0
1967	3.1	68.9	–0.1	–1.3	72.6	15,769.4	247.6	53,752.6
1968	3.3	72.0	–0.1	–6.1	68.1	14,713.8	253.0	54,688.4
1969	4.6	75.3	–0.1	1.3	93.8	20,290.1	277.2	59,942.3
1970	4.9	78.7	–0.1	7.1	113.0	24,523.0	297.8	64,644.4
1971	2.8	82.3	–0.1	2.1	78.9	17,099.4	303.8	65,874.5
1972	3.1	86.1	–0.1	–6.1	158.4	34,139.1	326.6	70,396.5
1973	3.9	90.2	–0.1	4.0	214.7	46,009.5	348.4	74,665.2
1974	4.1	94.1	–0.1	11.2	253.1	53,969.6	358.9	76,513.0
1975	2.9	97.9	–0.1	9.9	204.2	43,351.8	368.8	78,271.7
1976	3.0	101.9	–0.1	–14.1	218.8	46,299.7	368.0	77,873.3
1977	3.1	106.0	–0.2	–12.2	260.2	54,899.7	368.0	77,663.4
1978	3.2	110.2	–0.2	–8.5	268.0	56,382.6	376.7	79,266.6
1979	3.8	114.6	–0.2	8.9	275.0	57,722.5	403.1	84,591.3
1980	4.2	119.1	–0.2	10.2	292.7	61,231.2	423.6	88,631.9
1981	4.2	123.6	–0.2	–8.4	316.0	65,841.2	430.4	89,675.3
1982	4.5	128.0	–0.2	4.2	342.6	70,967.0	442.6	91,697.8
1983	4.3	132.6	–0.2	2.0	348.4	71,740.1	454.7	93,648.1
1984	4.3	137.3	–0.3	–10.2	244.9	50,175.0	471.2	96,514.7
1985	4.4	142.3	–0.3	7.1	260.4	53,110.7	487.1	99,358.2
1986	4.0	147.3	–0.3	–1.9	160.1	32,558.3	499.5	101,563.2
1987	4.0	152.6	–0.3	5.4	171.2	34,710.6	520.8	105,591.1
1988	4.3	158.0	–0.3	3.9	143.8	29,081.1	546.3	110,436.2
1989	4.8	163.4	–0.4	15.0	158.1	31,854.0	570.2	114,865.8
1990	4.5	168.9	–0.4	0.5	137.1	27,494.6	568.1	113,931.0
1991	4.3	174.4	–0.4	0.4	221.8	44,238.4	526.7	105,061.1
1992	4.1	179.8	–0.4	–5.3	214.2	42,492.5	502.9	99,751.1
1993	3.9	185.3	–0.3	–18.0	176.8	34,899.4	493.3	97,372.7
1994	4.3	191.1	–0.2	–12.8	177.9	34,956.4	520.1	102,224.0
1995	4.4	196.8	–0.2	–17.3	157.4	30,809.4	543.9	106,491.1
1996	4.5	202.7	–0.1	–0.5	195.0	38,058.3	570.3	111,280.2
1997	4.9	208.8	–0.1	–11.7	171.0	33,264.2	611.7	119,006.6
1998	4.5	215.1	–0.1	–3.4	168.3	32,655.7	641.4	124,458.9
1999	5.0	221.5	–0.2	0.4	162.9	31,509.8	671.8	130,353.5
2000	4.8	228.0	–0.2	–17.8	151.8	29,284.3	711.6	138,082.8

NB. FIM 1 = 0.168188 EUR and EUR 1 = FIM 5.945730 & FIM 1 = 0.154127 USD and USD 1 = FIM 6.488138 (25 Sep 2001).

Appendix 10 sources and notes :

Column B: Daly and Cobb (1989). p. 416–417 & Statistics Finland (2001). p. 12. & Statistics Finland (2000a). p. 4–5. & Statistics Finland (1984). p. 38–39.

Column C: Daly and Cobb (1989). p. 417 & Statistics Finland (1975). p. 19 & Statistics Finland (1970). p. 19.

Column D: Daly and Cobb (1989). p. 417. 420.

Column E: Daly and Cobb (1989). p. 420–421 & Taimio H. (1991). p. 134.

Column F: Daly and Cobb (1989). p. 421 & Statistics Finland. Unprinted records.

Column G: Daly and Cobb (1989). p. 421–422 & Statistics Finland (2000b). p. 97. & Statistics Finland (2000c). p. 126.

Column H: Daly and Cobb (1989). p. 422–423 & KELA (2000). p. 38. 47. & KELA (1999). p. 36–38.

Column I: Daly and Cobb (1989). p. 423 & Statistics Finland (2000a). p. 116–117. & Statistics Finland (1984). p. 72–73.

Column J: Daly and Cobb (1989). p. 423–424 & KELA (2000). p. 49. & KELA (1999). p. 47–49.

Column K: Daly and Cobb (1989). p. 424 & Statistics Finland (2000e). p. 30. & Statistics Finland (1999a). p. 41. & Statistics Finland (1995). p. 29. & Sauri. T. (1993). p. 71 & Suomen Gallup (1988). p. 11. & Aho. T. (1980).

Column L: Daly and Cobb (1989). p. 424–425 & Statistics Finland. Transport and Communications Statistical Yearbooks for Finland. 1986–2000.

Column M : Daly and Cobb (1989). p. 425 & Statistics Finland (2000f). p. 126–127. & Statistics Finland (1984). p. 116–117.

Column N: Daly and Cobb (1989). p. 425 & Statistics Finland (2000b). p. 111. & Statistics Finland (1999b). p. 110. & Statistics Finland (1998b). p. 16–17. & Finnish Motor Insurers' Association (1997).

Column O : Daly and Cobb (1989). p. 425–429 & Wahlström et al. (1996). p. 151 & Wahlström et al. (1992). p. 298. & Seppänen H. (1988). p. 79.

Column P: Daly and Cobb (1989). p. 429–431 & Statistics Finland (1998c). p. 137 & Statistics Finland (1994b). p. 134. Includes SO2. NOx. CO2. Particles and NMVOC -emissions. Prices used are 1997 prices deflated for each year: FIM 6.000 for SO2 emissions. FIM 5300 for NOx. FIM 183 for CO2. FIM 95.500 for particles and FIM 10.500 for NMVOC emissions.

Column Q: Daly and Cobb (1989). p. 431–432 & Lampinen R. (1991). p. 281.

Column R: Daly and Cobb (1989). p. 432–433 & FFRI 1960–2000. Price used are 1972 prices deflated for each year: USD 600 per Acre ie. USD 1.482.6 per hectare ie. FIM 6.146.9 per hectare. Exchange rate as January 31. 1972 : USD 1 = FIM 4.146. (For further information see Daly and Cobb (1989)).

Column S : Daly and Cobb (1989). p. 433–437 & Statistics Finland (2000d). p. 36. & Statistics Finland (1999c). p. 36. & Statistics Finland (1994a). p. 36.

Column T: Daly and Cobb (1989). p. 437–440 & Statistics Finland (2000a). p. 24–25. & Statistics Finland (2000f). p. 34–35. & Statistics Finland (1984). p. 50–51.

Column U: Daly and Cobb (1989). p. 440–441.

Column V: Daly and Cobb (1989). p. 442 & Statistics Finland (2000a). p. 46–47. & Statistics Finland (1984). p. 50–51.

Column W: Daly and Cobb (1989). p. 442–442 & Statistics Finland (2000a). p. 46–47. & Statistics Finland (1984). p. 50–51.

Column X: ISEW equals Column C added by Columns D through G. U and V and subtracted by Columns H through T; see Daly and Cobb (1989). p. 442.

Column Y: ISEW per population per each year; see Daly and Cobb (1989). p. 442.

Column Z: Daly and Cobb (1989). p. 443 & Statistics Finland (2000a). p. 24–25 & ETLA (1999). p. 57 & MoF (1999). p. 13. & Statistics Finland (1984). 50–51.

APPENDIX 11.
Progress of different eco-efficiencies in Finland

Progress of eco-efficiency 1, 2, 3 and 4 indicators

	EE1	EE2	EE3	EE4
1960	1,00	1,00	1,00	1,00
1961	1,04	0,97	1,03	0,98
1962	1,05	0,90	1,04	0,97
1963	1,09	0,91	1,08	0,99
1964	1,01	0,87	1,01	0,88
1965	0,97	0,76	0,97	0,81
1966	0,96	0,75	0,96	0,79
1967	1,06	0,91	1,05	0,86
1968	1,02	0,81	1,02	0,82
1969	1,03	1,02	1,03	0,76
1970	1,05	1,17	1,04	0,72
1971	1,03	0,79	1,01	0,70
1972	1,05	1,50	1,03	0,66
1973	1,08	1,96	1,05	0,64
1974	1,21	2,52	1,18	0,70
1975	1,39	2,29	1,36	0,80
1976	1,39	2,42	1,34	0,80
1977	1,43	2,95	1,35	0,82
1978	1,36	2,84	1,28	0,77
1979	1,31	2,61	1,24	0,70
1980	1,41	2,86	1,33	0,73
1981	1,49	3,18	1,39	0,75
1982	1,47	3,30	1,38	0,73
1983	1,37	3,05	1,28	0,67
1984	1,40	2,12	1,31	0,66
1985	1,38	2,15	1,30	0,64
1986	1,45	1,35	1,37	0,66
1987	1,42	1,36	1,33	0,63
1988	1,48	1,14	1,39	0,63
1989	1,48	1,19	1,37	0,61
1990	1,52	1,06	1,39	0,63
1991	1,58	1,91	1,40	0,70
1992	1,55	1,86	1,32	0,72
1993	1,58	1,59	1,34	0,74
1994	1,52	1,48	1,33	0,69
1995	1,59	1,32	1,41	0,70
1996	1,66	1,64	1,50	0,71
1997	1,67	1,36	1,54	0,68
1998	1,69	1,28	1,56	0,66
1999	1,71	1,21	1,59	0,64
2000	1,80	1,12	1,69	..

APPENDIX 11. Cont.

Progress of the eco-efficiency 5 indicators

	(1) Agriculture, hunting, forestry and fishing	(2) Mining and quarrying	(3) Construction	(4) Transport
1975	1,00	1,00	1,00	1,00
1976	1,00	0,99	0,95	0,96
1977	1,01	0,98	1,04	0,95
1978	0,92	1,05	0,96	0,96
1979	0,91	1,10	0,85	0,94
1980	1,17	1,07	0,86	0,98
1981	1,15	1,12	0,82	1,01
1982	1,16	1,22	0,80	0,99
1983	1,20	1,13	0,70	1,00
1984	1,25	1,10	0,70	0,99
1985	1,17	1,21	0,67	1,07
1986	1,18	1,45	0,66	1,01
1987	1,10	1,55	0,60	1,05
1988	1,08	1,61	0,68	1,06
1989	1,10	1,82	0,73	1,08
1990	1,19	1,88	0,74	1,11
1991	1,24	1,93	0,74	1,09
1992	1,13	2,02	0,72	1,07
1993	1,11	1,95	0,74	1,18
1994	1,12	2,22	0,63	1,22
1995	1,01	2,58	0,61	1,33
1996	1,07	2,62	0,69	1,37
1997	1,07	2,82	0,72	1,40
1998	1,00	2,29	0,72	1,45
1999	0,71	2,68	0,68	1,42
2000	0,74	2,11	0,69	1,48

	(3a) Civil engineering	(3b) Building	(5) Wood products	(6) Pulp and Paper	(7) Basic metal industry
1975	1,00	1,00	1,00	1,00	1,00
1976	0,97	0,93	0,97	1,32	0,90
1977	0,99	1,06	0,87	1,36	0,91
1978	0,89	0,99	0,88	1,33	1,02
1979	0,77	0,89	0,83	1,30	1,04
1980	0,74	0,93	0,86	1,34	1,13
1981	0,72	0,88	0,95	1,38	1,17
1982	0,67	0,88	1,01	1,43	1,20
1983	0,54	0,80	1,03	1,44	1,40
1984	0,55	0,79	1,01	1,47	1,42
1985	0,54	0,74	1,06	1,46	1,60
1986	0,53	0,74	1,05	1,52	1,88
1987	0,46	0,68	1,05	1,47	2,12
1988	0,47	0,80	1,12	1,46	2,16
1989	0,47	0,88	1,23	1,47	2,25
1990	0,48	0,88	1,19	1,59	2,26
1991	0,50	0,85	1,15	1,64	2,21
1992	0,48	0,88	1,05	1,67	2,61
1993	0,51	0,87	1,03	1,68	2,69
1994	0,47	0,73	1,00	1,73	2,85
1995	0,50	0,66	0,98	1,72	4,09
1996	0,52	0,80	1,02	1,72	3,93
1997	0,51	0,83	0,99	1,70	3,83
1998	0,51	0,83	0,99	1,70	4,01
1999	0,48	0,78	1,02	1,83	4,35
2000	0,46	0,82	1,04	1,62	4,39

APPENDIX 12. Progress of eco-efficiencies of certain industrial economies

Eco-efficiency 1 in Finland, Germany, Austria, the Netherlands and Japan 1975–1996

	Finland	Germany	Austria	Netherlands	Japan
1975	1.00	1.00	1.00	1.00	1.00
1976	0.99	1.03	1.00	1.05	1.03
1977	1.02	1.09	1.03	1.07	1.01
1978	0.98	1.09	1.03	1.10	1.01
1979	0.94	1.08	1.03	1.13	1.02
1980	1.02	1.12	1.02	1.14	1.06
1981	1.07	1.22	1.04	1.15	1.13
1982	1.07	1.29	1.07	1.14	1.20
1983	1.00	1.34	1.14	1.16	1.28
1984	1.03	1.33	1.10	1.20	1.28
1985	1.02	1.37	1.15	1.24	1.36
1986	1.07	1.39	1.18	1.21	1.39
1987	1.05	1.44	1.19	1.23	1.40
1988	1.10	1.42	1.21	1.26	1.39
1989	1.11	1.42	1.21	1.32	1.37
1990	1.15	1.45	1.24	1.38	1.35
1991	1.18	1.40	1.29	1.45	1.42
1992	1.19	1.38	1.29	1.49	1.53
1993	1.21	1.40	1.30	1.42	1.57
1994	1.17	1.34	1.25	1.38	1.57
1995	1.21	1.44	1.29	1.40	1.59
1996	1.31	1.46	1.30	1.38	1.65

Eco-efficiency 3 in Germany, the Netherlands and Austria 1975–1996

	Germany	Netherlands	Austria
1975	1.00	1.00	1.00
1976	0.96	1.04	1.00
1977	1.05	1.09	1.01
1978	1.00	1.13	1.02
1979	1.00	1.18	1.00
1980	1.17	1.17	0.95
1981	1.06	1.18	0.94
1982	1.09	1.17	0.94
1983	1.15	1.17	0.99
1984	1.07	1.15	0.93
1985	1.01	1.14	0.93
1986	0.94	1.06	0.94
1987	0.99	1.05	0.93
1988	1.02	1.01	0.90
1989	1.01	1.03	0.89
1990	1.02	1.03	0.88
1991	1.18	1.07	0.92
1992	1.20	1.07	0.92

***APPENDIX 12.* Cont.**

Eco-efficiency 4 in Finland, Germany, Japan, the Netherlands and Austria 1975–1996

	Finland	Germany	Japan	Netherlands	Austria
1975	1.00	1.00	1.00	1.00	1.00
1976	0.99	0.98	1.00	1.00	0.96
1977	1.03	1.01	0.94	1.01	0.94
1978	0.97	0.98	0.90	1.01	0.95
1979	0.87	0.94	0.87	1.02	0.91
1980	0.91	0.97	0.88	1.02	0.88
1981	0.94	1.06	0.92	1.04	0.91
1982	0.91	1.16	0.95	1.04	0.92
1983	0.83	1.19	0.99	1.05	0.96
1984	0.83	1.17	0.96	1.05	0.92
1985	0.80	1.20	0.98	1.06	0.93
1986	0.83	1.21	0.97	1.01	0.93
1987	0.78	1.25	0.94	1.02	0.93
1988	0.79	1.18	0.88	1.02	0.92
1989	0.76	1.12	0.84	1.03	0.89
1990	0.79	1.08	0.79	1.03	0.88
1991	0.87	0.83	0.80	1.07	0.89
1992	0.91	0.79	0.86	1.07	0.88
1993	0.94	0.81	0.88	1.02	0.88
1994	0.87	0.76	0.88	0.96	0.83
1995	0.87	0.80	0.87	0.96	0.84
1996	0.91	0.81	0.86	0.91	0.84

Eco-efficiencies 1 and 4 in Finland and Sweden 1987–1998

	Finland		Sweden	
	EE 1	EE 4	EE 1	EE 4
1987	1.00	1.00	1.00	1.00
1988	1.05	1.00	1.02	0.99
1989	1.05	0.97	0.98	0.94
1990	1.09	1.00	1.00	0.94
1991	1.12	1.11	1.05	1.01
1992	1.13	1.16	1.06	1.04
1993	1.15	1.20	1.02	1.02
1994	1.11	1.12	1.03	1.00
1995	1.15	1.11	1.01	0.95
1996	1.25	1.16	1.12	1.05
1997	1.22	1.08	1.15	1.06
1998	1.22	1.03	1.13	1.01

***APPENDIX 12.* Cont.**

Eco-efficiencies 1, 3 and 4 in the United States 1975–1994

	EE 1	EE 3	EE 4
1975	1.00	1.00	1.00
1976	1.01	0.97	0.97
1977	1.02	0.95	0.94
1978	1.02	0.92	0.90
1979	1.00	0.89	0.87
1980	1.09	0.98	0.95
1981	1.14	1.00	0.98
1982	1.21	1.09	1.07
1983	1.27	1.11	1.09
1984	1.19	0.98	0.96
1985	1.21	0.96	0.95
1986	1.22	0.94	0.94
1987	1.19	0.89	0.89
1988	1.20	0.87	0.87
1989	1.20	0.84	0.85
1990	1.19	0.82	0.83
1991	1.25	0.86	0.89
1992	1.22	0.81	0.84
1993	1.25	0.80	0.84
1994	1.21	0.74	0.79

APPENDIX 13.
Development of materials conversion to welfare in Finland

	GDP/DMF	HDI/GDP	HDI/DMF	GDP/DMF	ISEW/GDP	ISEW/DMF
1960	100,00	100,00	100,00	100,00	100,00	100,00
1961	104,86	93,44	97,98	104,86	92,92	97,43
1962	106,05	91,23	96,75	106,05	86,00	91,20
1963	111,49	88,81	99,02	111,49	83,55	93,16
1964	104,07	84,84	88,29	104,07	85,52	89,00
1965	99,55	81,00	80,64	99,55	78,82	78,47
1966	98,99	79,54	78,74	98,99	78,23	77,44
1967	109,84	78,27	85,97	109,84	86,58	95,10
1968	106,71	76,91	82,07	106,71	79,32	84,64
1969	107,26	70,55	75,67	107,26	99,75	106,99
1970	108,78	65,95	71,74	108,78	111,76	121,57
1971	107,56	64,67	69,55	107,56	76,43	82,20
1972	109,99	60,14	66,15	109,99	142,62	156,87
1973	113,76	56,41	64,17	113,76	181,15	206,07
1974	128,63	54,81	70,50	128,63	207,33	266,69
1975	149,91	53,53	80,24	149,91	162,59	243,73
1976	148,29	53,84	79,83	148,29	174,34	258,52
1977	152,79	53,91	82,37	152,79	206,60	315,66
1978	146,40	52,93	77,49	146,40	207,94	304,42
1979	140,56	49,81	70,02	140,56	199,90	281,00
1980	152,52	47,55	72,53	152,52	202,36	308,64
1981	161,01	46,74	75,26	161,01	213,95	344,48
1982	160,06	45,50	72,83	160,06	224,84	359,88
1983	150,35	44,46	66,85	150,35	222,55	334,60
1984	154,07	43,16	66,50	154,07	151,31	233,13
1985	152,79	42,07	64,28	152,79	155,99	238,33
1986	160,66	41,27	66,30	160,66	93,61	150,39
1987	157,74	39,81	62,79	157,74	96,03	151,48
1988	165,09	38,20	63,07	165,09	77,04	127,19
1989	166,09	36,53	60,67	166,09	80,55	133,79
1990	171,63	36,66	62,92	171,63	69,82	119,82
1991	179,30	39,22	70,33	179,30	120,49	216,04
1992	176,21	40,60	71,55	176,21	120,38	212,13
1993	180,72	41,12	74,31	180,72	100,50	181,63
1994	174,55	39,77	69,41	174,55	97,26	169,76
1995	183,15	38,47	70,46	183,15	82,89	151,81
1996	192,09	37,07	71,21	192,09	98,77	189,73
1997	194,10	35,03	67,99	194,10	81,46	158,11
1998	196,29	33,40	65,56	196,29	76,12	149,42
1999	198,65	32,39	64,35	198,65	70,86	140,76
2000	210,31	..	..	209,38	62,43	130,71

.. = data not available.

APPENDIX 14.
Development of Sustainable ne Benefit Measure (SBM) in Finland (FIM million, rp)

Year	Net National Income	Env. Expendi-ture Total	Negative side-effects of economic growth	Changes in Natural Resources	Other changes in the eco-systems	Sustainable net Benefit Measure
A	**A (+)**	**B (-)**	**C (-)**	**D (-)**	**E (-)**	**SBM**
1960	166,316	2,577	9,716	6,790	101,506	45,726
1961	178,676	3,063	10,341	7,864	107,002	50,405
1962	183,133	3,402	10,778	6,886	111,403	50,664
1963	188,653	3,689	11,348	6,561	116,881	50,174
1964	199,082	3,677	11,933	6,477	123,887	53,107
1965	209,797	3,752	12,732	5,629	129,890	57,794
1966	213,886	3,933	13,227	5,239	135,151	56,335
1967	217,856	4,038	13,390	5,154	141,317	53,957
1968	222,028	3,902	13,718	5,308	149,140	49,961
1969	244,659	3,685	14,602	6,129	157,323	62,920
1970	261,560	4,192	15,486	6,871	163,603	71,407
1971	264,489	5,562	16,878	6,295	176,033	59,721
1972	284,099	5,735	18,383	6,181	183,975	69,825
1973	302,379	6,178	19,200	6,084	191,820	79,097
1974	309,391	6,330	18,861	5,340	198,025	80,834
1975	312,426	6,131	20,058	2,236	202,967	81,034
1976	310,153	5,034	21,083	2,003	210,779	71,254
1977	306,766	4,869	21,702	3,540	216,902	59,753
1978	313,329	4,643	22,483	4,227	225,958	56,018
1979	337,430	4,379	24,501	5,958	235,382	67,210
1980	353,303	4,722	25,607	5,265	246,504	71,205
1981	358,147	4,599	26,895	4,357	212,054	110,242
1982	368,645	4,815	28,073	3,710	217,500	114,547
1983	378,128	4,482	29,705	3,242	222,451	118,249
1984	392,792	4,580	30,482	3,409	229,330	124,991
1985	405,715	5,327	31,600	1,964	238,597	128,228
1986	415,417	4,833	33,473	1,937	301,791	73,382
1987	432,280	5,228	34,590	1,368	312,208	78,886
1988	454,774	6,021	37,186	2,589	325,453	83,525
1989	472,475	7,304	39,110	2,498	337,460	86,103
1990	464,386	6,735	38,958	1,455	348,332	68,907
1991	421,281	7,895	37,263	368	281,818	93,937
1992	398,409	9,151	36,347	1,954	287,770	63,187
1993	389,138	8,789	34,139	961	293,540	51,710
1994	415,704	7,887	34,349	857	301,276	71,335
1995	441,797	9,757	33,856	1,741	306,845	89,598
1996	465,854	10,388	34,584	935	314,367	105,580
1997	502,944	10,576	36,474	2,333	321,059	132,502
1998	534,481	10,123	38,779	2,581	327,285	155,713
1999	554,377	10,192	40,316	2,668	333,881	167,320
2000	585,528	9,777	40,510	3,066	340,179	191,996

NB. SBM = NNI – TE – NE – NR – OE. SBM is the Sustainable net Benefit Measure of production, NNI is the Net National Income, TE is the Total Environmental Expenditures of a society, NE is the Negative side-Effects of the economic activities, NR is the human caused change in Natural Resources (in quantity and quality), and OE is the Other human caused changes in Ecosystems (in quantity and quality).

NB2 . FIM 1 = 0.168188 EUR and EUR 1 = FIM 5.945730 & FIM 1 = 0.154127 USD and USD 1 = FIM 6.488138 (25 Sep 2001).

APPENDIX 15.
Progress of DMF, TMF and emissions of carbon dioxide per capita in Finland in 1960-2000 and forecasts till 2030 (1960=100)

	DMF pc	TMF pc	CO_2 pc		DMF pc	TMF pc	CO_2 pc
1960	100,00	100,00	100,00	1996	140,53	149,88	344,52
1961	101,90	99,58	99,24	1997	147,38	152,51	333,46
1962	103,06	99,14	107,95	1998	153,11	154,52	319,23
1963	100,53	99,13	123,19	1999	157,17	158,25	315,52
1964	112,72	109,78	142,13	2000	156,45	165,88	299,04
1965	123,66	118,92	159,41	2001	155,72	165,84	301,13
1966	126,84	119,43	178,20	2002	155,00	165,80	303,24
1967	116,16	112,77	179,74	2003	154,28	165,76	305,35
1968	121,77	117,31	200,55	2004	153,56	165,72	307,49
1969	134,45	128,17	238,07	2005	152,85	165,68	309,64
1970	143,05	130,34	248,06	2006	152,14	165,65	311,80
1971	147,68	132,58	247,15	2007	151,43	165,61	313,98
1972	154,58	138,11	269,26	2008	150,72	165,57	316,17
1973	158,98	143,60	296,40	2009	150,02	165,53	318,38
1974	144,51	134,01	269,76	2010	149,33	165,49	320,61
1975	127,80	121,91	268,22	2011	148,63	165,45	322,85
1976	128,81	126,15	305,87	2012	147,94	165,42	325,11
1977	125,15	123,84	300,97	2013	147,25	165,38	327,38
1978	132,03	134,43	325,64	2014	146,57	165,34	329,67
1979	145,59	143,32	321,82	2015	145,89	165,30	331,97
1980	141,42	142,59	325,49	2016	145,21	165,26	334,29
1981	136,65	128,74	269,05	2017	144,53	165,23	336,63
1982	140,58	133,84	258,15	2018	143,86	165,19	338,98
1983	152,21	141,82	254,23	2019	143,19	165,15	341,35
1984	153,27	146,52	261,15	2020	142,53	165,11	343,73
1985	158,74	153,81	294,96	2021	141,86	165,07	346,13
1986	154,93	148,00	285,29	2022	141,20	165,03	348,55
1987	160,52	152,69	304,85	2023	140,55	165,00	350,99
1988	160,17	154,43	301,66	2024	139,89	164,96	353,44
1989	166,79	159,64	299,28	2025	139,24	164,92	355,91
1990	160,75	153,88	310,32	2026	138,59	164,88	358,40
1991	143,45	139,68	304,51	2027	137,95	164,84	360,90
1992	140,33	135,99	292,18	2028	137,31	164,81	363,43
1993	134,60	136,49	294,17	2029	136,67	164,77	365,97
1994	144,25	150,16	328,39	2030	136,03	164,73	368,52
1995	142,17	147,52	309,74				

APPENDIX 16.
Progress of population in 1960–2000 and a projection till 2030 (persons)

1960	4,429,634	1996	5,124,573
1961	4,461,005	1997	5,139,835
1962	4,491,443	1998	5,153,500
1963	4,523,309	1999	5,171,302
1964	4,548,543	2000	5,182,107
1965	4,563,732	2001	5,185,365
1966	4,580,869	2002	5,194,501
1967	4,605,744	2003	5,203,085
1968	4,626,469	2004	5,211,231
1969	4,623,785	2005	5,218,984
1970	4,606,307	2006	5,226,393
1971	4,612,124	2007	5,233,455
1972	4,639,657	2008	5,240,216
1973	4,666,081	2009	5,246,669
1974	4,690,574	2010	5,252,796
1975	4,711,440	2011	5,258,596
1976	4,725,664	2012	5,264,052
1977	4,738,902	2013	5,269,154
1978	4,752,528	2014	5,273,874
1979	4,764,690	2015	5,278,197
1980	4,779,535	2016	5,282,086
1981	4,799,964	2017	5,285,532
1982	4,826,933	2018	5,288,475
1983	4,855,787	2019	5,290,842
1984	4,881,803	2020	5,292,599
1985	4,902,206	2021	5,293,619
1986	4,918,154	2022	5,293,799
1987	4,932,123	2023	5,293,059
1988	4,946,481	2024	5,291,273
1989	4,964,371	2025	5,288,345
1990	4,986,431	2026	5,284,207
1991	5,013,740	2027	5,278,805
1992	5,041,992	2028	5,272,117
1993	5,066,447	2029	5,264,116
1994	5,088,333	2030	5,254,768
1995	5,107,790		

Source: Statistics Finland 1998a.

APPENDIX 17.
Progress of ISEW, HDI and GDP per capita in 1985–2000 and forecasts till 2030 (1985=100)

	ISEW pc	HDI	GDP pc
1985	100,00	100,00	100,00
1986	61,30	100,53	102,16
1987	65,36	101,06	106,16
1988	54,76	101,58	110,87
1989	59,98	102,11	116,15
1990	51,77	102,52	115,67
1991	83,29	102,82	107,84
1992	80,01	102,90	103,67
1993	65,71	103,01	101,99
1994	65,82	103,56	105,57
1995	58,01	104,01	109,17
1996	71,66	104,24	113,18
1997	62,63	104,70	119,94
1998	61,49	105,16	126,00
1999	59,33	106,08	131,06
2000	55,14	106,53	138,54
2001	54,16	106,98	141,68
2002	53,20	107,43	144,88
2003	52,26	107,88	148,16
2004	51,34	108,34	151,51
2005	50,43	108,80	154,94
2006	49,54	109,26	158,45
2007	48,66	109,72	162,04
2008	47,80	110,18	165,70
2009	46,95	110,65	169,45
2010	46,12	111,11	173,29
2011	45,31	111,58	177,21
2012	44,51	112,05	181,22
2013	43,72	112,53	185,32
2014	42,94	113,00	189,51
2015	42,18	113,48	193,80
2016	41,44	113,96	198,19
2017	40,70	114,44	202,67
2018	39,98	114,93	207,26
2019	39,28	115,41	211,95
2020	38,58	115,90	216,75
2021	37,90	116,39	221,65
2022	37,23	116,88	226,67
2023	36,57	117,37	231,80
2024	35,92	117,87	237,05
2025	35,29	118,37	242,41
2026	34,66	118,87	247,90
2027	34,05	119,37	253,51
2028	33,45	119,88	259,24
2029	32,85	120,38	265,11
2030	32,27	120,89	271,11

APPENDIX 18.
Forecasts for eco-efficiencies 1, 2, 3 and 4 till 2030 (1960=1,00)

	EE1	EE2	EE3	EE4
2000	1,80	1,69	1,12	0,64
2001	1,82	1,71	1,11	0,63
2002	1,84	1,72	1,10	0,63
2003	1,86	1,74	1,09	0,62
2004	1,88	1,76	1,08	0,62
2005	1,90	1,77	1,07	0,61
2006	1,93	1,79	1,06	0,61
2007	1,95	1,81	1,05	0,60
2008	1,97	1,83	1,04	0,60
2009	1,99	1,85	1,03	0,59
2010	2,01	1,86	1,02	0,59
2011	2,04	1,88	1,01	0,58
2012	2,06	1,90	1,00	0,58
2013	2,08	1,92	1,00	0,58
2014	2,11	1,94	0,99	0,57
2015	2,13	1,96	0,98	0,57
2016	2,15	1,98	0,97	0,56
2017	2,18	1,99	0,96	0,56
2018	2,20	2,01	0,95	0,55
2019	2,23	2,03	0,94	0,55
2020	2,25	2,05	0,94	0,54
2021	2,28	2,07	0,93	0,54
2022	2,30	2,09	0,92	0,53
2023	2,33	2,12	0,91	0,53
2024	2,36	2,14	0,90	0,53
2025	2,38	2,16	0,90	0,52
2026	2,41	2,18	0,89	0,52
2027	2,44	2,20	0,88	0,51
2028	2,47	2,22	0,87	0,51
2029	2,49	2,24	0,86	0,51
2030	2,52	2,26	0,86	0,50

APPENDIX 19.
Progress of eco-efficiencies 2, 3, 4 and 6 and forecasts till 2025

Actual eco-efficiencies 2, 3, 4 and 6 during 1960 – 2000

	EE2	EE3	EE4	EE6
1960	1,00	1,00	1,00	1,00
1961	1,04	0,97	0,98	1,07
1962	1,05	0,90	0,97	1,06
1963	1,09	0,91	0,99	1,07
1964	1,01	0,87	0,88	1,00
1965	0,97	0,76	0,81	0,99
1966	0,96	0,75	0,79	0,94
1967	1,06	0,91	0,86	0,98
1968	1,02	0,81	0,82	0,86
1969	1,03	1,02	0,76	0,99
1970	1,05	1,17	0,72	1,06
1971	1,03	0,79	0,70	0,86
1972	1,05	1,50	0,66	0,96
1973	1,08	1,96	0,64	1,05
1974	1,21	2,52	0,70	1,18
1975	1,39	2,29	0,80	1,34
1976	1,39	2,42	0,80	1,16
1977	1,43	2,95	0,82	1,00
1978	1,36	2,84	0,77	0,88
1979	1,31	2,61	0,70	0,95
1980	1,41	2,86	0,73	1,04
1981	1,49	3,18	0,75	1,66
1982	1,47	3,30	0,73	1,66
1983	1,37	3,05	0,67	1,57
1984	1,40	2,12	0,66	1,65
1985	1,38	2,15	0,64	1,62
1986	1,45	1,35	0,66	0,95
1987	1,42	1,36	0,63	0,97
1988	1,48	1,14	0,63	1,02
1989	1,48	1,19	0,61	1,01
1990	1,52	1,06	0,63	0,83
1991	1,58	1,91	0,70	1,27
1992	1,55	1,86	0,72	0,87
1993	1,58	1,59	0,74	0,73
1994	1,52	1,48	0,69	0,94
1995	1,59	1,32	0,70	1,20
1996	1,66	1,64	0,71	1,42
1997	1,67	1,36	0,68	1,69
1998	1,69	1,28	0,66	1,91
1999	1,71	1,21	0,64	2,00
2000	1,69	1,12	0,64*)	2,29

*) = forecast.

APPENDIX 19. Cont.

Forecasts for eco-efficiencies 2, 3, 4 and 6 from 2001 to 2025

	EE2	EE3	EE4	EE6
2001	1,71	1,11	0,63	2,35
2002	1,72	1,10	0,63	2,41
2003	1,74	1,09	0,62	2,48
2004	1,76	1,08	0,62	2,54
2005	1,77	1,07	0,61	2,61
2006	1,79	1,06	0,61	2,68
2007	1,81	1,05	0,6	2,76
2008	1,83	1,04	0,6	2,83
2009	1,85	1,03	0,59	2,91
2010	1,86	1,02	0,59	2,98
2011	1,88	1,01	0,58	3,06
2012	1,90	1,00	0,58	3,15
2013	1,92	1,00	0,58	3,23
2014	1,94	0,99	0,57	3,32
2015	1,96	0,98	0,57	3,41
2016	1,98	0,97	0,56	3,5
2017	1,99	0,96	0,56	3,6
2018	2,01	0,95	0,55	3,69
2019	2,03	0,94	0,55	3,79
2020	2,05	0,94	0,54	3,89
2021	2,07	0,93	0,54	4
2022	2,09	0,92	0,53	4,11
2023	2,12	0,91	0,53	4,22
2024	2,14	0,90	0,53	4,33
2025	2,16	0,90	0,52	4,45

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