Energy Indicators for Sustainable Development: Guidelines and Methodologies

IAEA
International Atomic Energy Agency

United Nations Department of Economic and Social Affairs

International Energy Agency

eurostat
Eurostat

European Environment Agency

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UNITED NATIONS DEPARTMENT OF ECONOMIC AND SOCIAL AFFAIRS,
INTERNATIONAL ENERGY AGENCY,
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FOREWORD

This publication is the product of an international initiative to define a set of Energy Indicators for Sustainable Development (EISD) and corresponding methodologies and guidelines. The successful completion of this work is the result of an intensive effort led by the International Atomic Energy Agency (IAEA) in cooperation with the United Nations Department of Economic and Social Affairs (UNDESA), the International Energy Agency (IEA), Eurostat and the European Environment Agency (EEA).

The thematic framework, guidelines, methodology sheets and energy indicators set out in this publication reflect the expertise of these various agencies, recognized worldwide as leaders in energy and environmental statistics and analysis. While each agency has an active indicator programme, one goal of this joint endeavour has been to provide users with a consensus by leading experts on definitions, guidelines and methodologies for the development and worldwide use of a single set of energy indicators.

No set of energy indicators can be final and definitive. To be useful, indicators must evolve over time to fit country-specific conditions, priorities and capabilities. The purpose of this publication is to present one set of EISD for consideration and use, particularly at the national level, and to serve as a starting point in the development of a more comprehensive and universally accepted set of energy indicators relevant to sustainable development. It is hoped that countries will use the EISD to assess their energy systems and to track their progress towards nationally defined sustainable development goals and objectives. It is also hoped that users of the information presented in this publication will contribute to refinements of energy indicators for sustainable development by adding their own unique perspectives to what is presented herein.

The work of devising energy indicators in the context of sustainable development was initiated in 1999 by Arshad Khan and Garegin Aslanian at the Planning and Economic Studies Section of the IAEA. They spearheaded the complex process of selecting, defining and validating an appropriate set of energy-related indicators consonant with the larger effort on Indicators of Sustainable Development (ISD) developed by Member States of the United Nations and international organizations under the umbrella of Agenda 21 and the United Nations Commission on Sustainable Development (CSD). Their preliminary work was presented by the IAEA in cooperation with the IEA in the 9th session of the CSD in 2001. This effort was followed by an international initiative to refine the energy indicators, created as a partnership in 2002 and registered with the World Summit on Sustainable Development.

Under this partnership, an ad hoc interagency expert group started consultations to develop a consensus on a single set of energy indicators, methodologies and guidelines for general use. The members of this group were Kathleen Abdalla from UNDESA, Roeland Mertens and Rosemary Montgomery from Eurostat, Aphrodite Mourelatou and Peter Taylor from the EEA, Fridtjof Unander from the IEA and Ivan Vera (Project Coordinator) from the IAEA.

Over the past two years, these committee members have made outstanding contributions to the substance and quality of the present report and its attempt to circumscribe a challenging emerging subject. Their dedication to finishing a unified report with worldwide applicability has ensured its success, and their congenial and professional spirit of cooperation was crucial for reaching consensus for the publication of this five-

agency report. Their work also benefited greatly from the contributions of others, including Kui-nang Mak from UNDESA; Carmen Difiglio from the IEA; August Götzfried, Nikolaos Roubanis and Peter Tavoularidis from Eurostat; Tobias Wiesenthal, Andre Jol, David Stanners and Jeff Huntington from the EEA; Hans-Holger Rogner, Lucille Langlois, Greg Csullog, Irej Jalal and Ferenc Toth from the IAEA; and Ellen Bergschneider, who provided editorial support.

CONTENTS

1. INTRODUCTION

'Sustainable development' has been defined best by the Brundtland Commission as 'development that meets the needs of the present without compromising the ability of future generations to meet their own needs'.[1] Adequate and affordable energy supplies have been key to economic development and the transition from subsistence agricultural economies to modern industrial and service-oriented societies. Energy is central to improved social and economic well-being, and is indispensable to most industrial and commercial wealth generation. It is key for relieving poverty, improving human welfare and raising living standards. But however essential it may be for development, energy is only a means to an end. The end is good health, high living standards, a sustainable economy and a clean environment. No form of energy — coal, solar, nuclear, wind or any other — is good or bad in itself, and each is only valuable in as far as it can deliver this end.

Much of the current energy supply and use, based, as it is, on limited resources of fossil fuels, is deemed to be environmentally unsustainable. There is no energy production or conversion technology without risk or without waste. Somewhere along all energy chains — from resource extraction to the provision of energy services — pollutants are produced, emitted or disposed of, often with severe health and environmental impacts. Even if a technology does not emit harmful substances at the point of use, emissions and wastes may be associated with its manufacture or other parts of its life cycle. Combustion of fossil fuels is chiefly responsible for urban air pollution, regional acidification and the risk of human-induced climate change. The use of nuclear power has created a number of concerns, such as the storage or disposal of high-level radioactive waste and the proliferation of nuclear weapons. The non-commercial use of biomass in some developing countries contributes to desertification and loss of biodiversity.

Moreover, about one-third of the world's population still relies on the use of animal power and non-commercial fuels. Some 1.7 billion people have no access to electricity. Many areas in the world have no reliable and secure energy supplies. This lack of access to modern energy services severely limits socioeconomic development — an integral part of sustainable development. Nonetheless, because of improved technology and an increased understanding of the effects and impacts of energy and energy systems, a developing country today can make the transition from an agricultural to an industrial economy with much lower costs and with less environmental damage than today's developed countries were subjected to during their transition.

Achieving sustainable economic development on a global scale will require the judicious use of resources, technology, appropriate economic incentives and strategic policy planning at the local and national levels. It will also require regular monitoring of the impacts of selected policies and strategies to see if they are furthering sustainable development or if they should be adjusted. It is important to be able to measure a country's state of development and to monitor its progress or lack of

[1] WCED (World Commission on Environment and Development), 1987. *Our Common Future.* Oxford, UK: Oxford University Press.

progress towards sustainability. First, policymakers need to know their country's current status concerning energy and economic sustainability, what needs to be improved and how these improvements can be achieved. Second, it is important for policymakers to understand the implications of selected energy, environmental and economic programmes, policies and plans, and their impacts on the shaping of development and on the feasibility of making this development sustainable. Third, inevitably there will be trade-offs. In short, there is an imminent need for informed and balanced choices to be made on policy, investment and corrective action.

When choosing energy fuels and associated technologies for the production, delivery and use of energy services, it is essential to take into account economic, social and environmental consequences. Policymakers need methods for measuring and assessing the current and future effects of energy use on human health, human society, air, soil and water. They need to determine whether current energy use is sustainable and, if not, how to change it so that it is. This is the purpose of the energy indicators presented in this report, which address important issues within three of the major dimensions of sustainable development: economic, social and environmental.

The indicators are not merely data; rather, they extend beyond basic statistics to provide a deeper understanding of the main issues and to highlight important relations that are not evident using basic statistics. They are essential tools for communicating energy issues related to sustainable development to policymakers and to the public, and for promoting institutional dialogue. Each set of indicators expresses aspects or consequences of the production and use of energy. Taken together, the indicators give a clear picture of the whole system, including interlinkages and trade-offs among various dimensions of sustainable development, as well as the longer-term implications of current decisions and behaviour. Changes in the indicator values over time mark progress or lack of progress towards sustainable development.

The same value for a given energy indicator might not mean the same thing for two different countries. The meaning will depend on the state of development of each country, the nature of its economy, its geography, the availability of indigenous energy resources and so on. Caution, therefore, needs to be applied when using such indicators for cross-country comparisons. Nonetheless, changes in the value of each indicator over time will help to quantify the progress of each country.[2] Instead of relying on abstract analysis, policymakers will have a simple set of figures to guide their decisions and monitor the results of their policies.

Consider an example from medicine. A doctor can evaluate a patient's health using a handful of numbers: blood pressure, pulse rate, weight-to-height ratio, cholesterol level and so on. By watching how these numbers change over time, the doctor can advise the patient whether his or her health is improving or deteriorating. This will help the patient to choose the best diet, exercise regimen and medicine. Of course, the numbers do not mean the same thing for all patients. A naturally stocky person, even

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[2] Indicators are useful for monitoring progress towards specific country goals. For example, to reach an annual limit on a set of emissions from the energy sector, it would be sensible to identify the values of appropriate indicators that would be necessary to meet this goal. With knowledge of the energy sector, policymakers can identify the indicators over which they have the most control. Progress is then more easily monitored and policy is often more easily implemented by using these indicators rather than focusing solely on the goal.

in perfect health, will have a higher weight-to-height ratio than a naturally slight person; some people naturally have rather high blood pressure. But by monitoring the numbers over time, the doctor can advise different patients on their progress towards good health.

The indicators presented here constitute a core set of Energy Indicators for Sustainable Development (EISD) with corresponding methodologies and guidelines useful to policymakers, energy analysts and statisticians. Some indicators focus on the delivery of essential energy services for reducing poverty and improving living conditions, while other indicators focus on environmental effects. It is important to take not only the economic but also these social and environmental issues into account when deciding on policies. The role of the analyst is to select, weigh and present to policymakers appropriate indicators for the situation in their own country so as to foster development in a sustainable manner.

Each of the EISD presented in this report might, in fact, represent a set of several indicators, as many of the issues touched on are best analysed using a group of related indicators.

Contents of the Report

This report includes five chapters, four annexes, a bibliography and a list of related Internet sites. Chapter 2 presents a background summary and short descriptions of work on energy indicators undertaken in participating agencies. Chapter 3 includes the list of indicators classified according to dimensions, themes and sub-themes. The chapter also discusses the dimensions, themes and frameworks used to define the indicators. Chapter 4 provides guidelines on how to select and use the indicators and discusses their limitations, pitfalls and constraints to ensure meaningful analysis and to avoid basic statistical misinterpretations. Chapter 5 contains methodology sheets for each of the 30 EISD. Annex 1 is a glossary of selected terms used in the report. Annex 2 is a list of acronyms. Annex 3 includes a summary of a decomposition method to analyse energy intensities. Annex 4 provides units and conversion factors.

The methodology sheets make up the bulk of the report. They give basic descriptions, methods, data availability, units, alternative definitions and relevance to sustainable development. These sheets are complete descriptions of the indicators, prepared to assist users in the elaboration, construction and implementation of the EISD. They include the main and alternative definitions, the components of each indicator, the units in which they are measured, instructions on how to construct them, data issues and sources. A country implementing the EISD may choose to use an alternative definition for a particular indicator that better fits that country's specific circumstances.

2. BACKGROUND

Since the publication of the Brundtland Report in 1987, various international and national organizations have been developing sets of indicators to measure and assess one or more aspects of sustainable development. These efforts received a major boost following the adoption of Agenda 21 at the Earth Summit in 1992, which (in Chapter 40) specifically asks countries and international governmental and nongovernmental organizations to develop the concept of indicators of sustainable development and to harmonize them at the national, regional and global levels.

2.1 The United Nations Effort on Indicators of Sustainable Development

In response to decisions taken by the United Nations (UN) Commission on Sustainable Development (CSD) and to Chapter 40 of Agenda 21, in 1995 the UN Department of Economic and Social Affairs (UNDESA) began working to produce a set of indicators for sustainable development. At the outset, the indicators considered the four major dimensions of sustainable development: social, economic, environmental and institutional. Within these categories, indicators were classified according to their driving force, state and response (DSR) characters following a conceptual framework widely used for environmental indicator development. However, after national testing, the Expert Group on Indicators of Sustainable Development (ISD) changed from the DSR format to policy issues or main themes and sub-themes, with energy as a sub-theme with three indicators (annual energy use per capita, share of consumption of renewable energy resources and intensity of energy use). This was done to better facilitate national policymaking and performance measurements. The revised framework also addresses future risks, correlation between themes, sustainability goals and basic social needs.[1]

At one point, the UN ISD package included more than 130 indicators. The latest version of the package includes 58 indicators classified into four dimensions, 15 themes and 38 sub-themes. The number of indicators was greatly restricted when it became apparent that a large set of indicators was unwieldy and difficult to use effectively.

2.2 Energy Indicators and Sustainable Development: The Commission on Sustainable Development and the Johannesburg Plan of Implementation

The initial work on energy indicators undertaken by the International Atomic Energy Agency (IAEA) with contributions from UNDESA, the International Energy Agency (IEA) and other international and national organizations was presented at the ninth session of the Commission on Sustainable Development (CSD-9) in 2001, under the name 'Indicators for Sustainable Energy Development' (ISED). During this session energy was a major theme. Improving affordability of and accessibility to modern energy services for the rural and urban poor as well as promoting less wasteful use of energy resources by the rich were among the most pressing issues identified at CSD-9. The dissemination of information on clean and efficient technologies, good practice

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[1] UNDESA, 2001. *Indicators of Sustainable Development: Guidelines and Methodologies*, 2nd edition, September. New York, NY, USA: United Nations Department of Economic and Social Affairs.

and adequate policies was recognized as an important contribution to providing energy for sustainable development. The international community noted that relevant information could guide decision makers to suitable policy and energy supply options, and that energy indicators were a tool for monitoring the consequences of such choices. Decisions taken at CSD-9 pertinent to the refinement of the ISED included the identification of the key energy issues of accessibility, energy efficiency, renewable energy, advanced fossil fuel technologies, nuclear energy technologies, rural energy, and energy and transport.

Energy was discussed the following year at the World Summit on Sustainable Development (WSSD) held in Johannesburg. The international community built on decisions taken at CSD-9 and reconfirmed access to energy as important in the Millennium Development Goal of halving the proportion of people living in poverty by 2015. The WSSD agreed to facilitate access for the poor to reliable and affordable energy in the context of larger national policies to foster sustainable development. The Summit also called for changes to unsustainable patterns of energy production and use. The Johannesburg Plan of Implementation (JPOI) that came out of the Summit urges all nations, groups and institutions to take immediate action to achieve the goals of sustainable development set out in Agenda 21 and at the Earth Summit +5, and further elaborated in the JPOI.

The core set of energy indicators, now called Energy Indicators for Sustainable Development (EISD), has been designed to provide information on current energy-related trends in a format that aids decision making at the national level in order to help countries assess effective energy policies for action on sustainable development. The indicators can help to guide the implementation of actions urged at the WSSD, namely, (i) to integrate energy into socioeconomic programmes, (ii) to combine more renewable energy, energy efficiency and advanced energy technologies to meet the growing need for energy services, (iii) to increase the share of renewable energy options, (iv) to reduce the flaring and venting of gas, (v) to establish domestic programmes on energy efficiency, (vi) to improve the functioning and transparency of information in energy markets, (vii) to reduce market distortions and (viii) to assist developing countries in their domestic efforts to provide energy services to all sectors of their populations.

The indicators should make it easier to see which programmes are necessary for sustainable development. This should identify what energy statistics need to be collected as well as the necessary scope of regional and national databases.

2.3 Energy Indicator Efforts in Participating Agencies

This report is the result of an interagency effort led by the IAEA in cooperation with UNDESA, the IEA, the Statistical Office of the European Communities (Eurostat) and the European Environment Agency (EEA). It is a joint endeavour intended to eliminate duplication and provide users with a single set of energy indicators applicable in every country. In addition to the interagency cooperative work on EISD, each of these agencies has ongoing programmes on energy or energy/environmental indicators, which are to some extent interlinked. These programmes are designed to monitor and assess sustainable development trends in their corresponding Member States and regions. These activities complement the joint effort on harmonization presented in this report. A short description of these various agency programmes is presented below.

2.3.1 The International Atomic Energy Agency (IAEA) and the ISED/EISD Effort

The IAEA initiated this indicator project in 1999 in cooperation with various international organizations, including the IEA and UNDESA, and some Member States of the IAEA. As previously mentioned, the original name was Indicators for Sustainable Energy Development (ISED). This name was later modified to Energy Indicators for Sustainable Development (EISD) to reflect the view held by some users that 'sustainable energy development' refers only to renewable energy and not to the broader spectrum of energy choices. The project was conceived (i) to fill the need for a consistent set of energy indicators applicable worldwide, (ii) to assist countries in the energy and statistical capacity building necessary to promote energy sustainability and (iii) to supplement the work on general indicators being undertaken by the CSD.

The project has two phases. In the first phase (2000–2001), a potential set of energy indicators for sustainable development was identified and the conceptual framework to define and classify these indicators was developed. During the second phase, which began in 2002, the original set of indicators and framework were refined, and the practical utility of the indicator set in a variety of applications is being demonstrated by incorporating the indicators into relevant databases and analytical tools, using them in ongoing statistical analyses (capacity building) and helping countries to use the system to track their energy strategies in conformity with their national objectives of sustainable development.

In the first phase, the original set of 41 indicators was developed and defined in terms of their assigned DSR characters, with desirable responses identified for improving the sustainability of energy systems. A conceptual framework was developed that defined major themes and sub-themes, and systematic cross-linkages among indicators. The results of the first phase were presented at CSD-9 in April 2001.[2]

The second phase started with a coordinated effort led by the IAEA to implement the set of EISD in the following countries: Brazil, Cuba, Lithuania, Mexico, Russian Federation, Slovak Republic and Thailand. These countries have selected particular subsets of the EISD most relevant to their energy priorities and have applied these indicators in analyses of their current and potential future energy systems and policies. This implementation programme concludes in 2005 with reports summarizing the findings. Also during the second phase, the EISD project was classified as a WSSD Partnership and was officially registered as such with the CSD.

The second phase has also included a parallel coordinated effort with other international organizations (the IEA, UNDESA, Eurostat and the EEA) involved in the development of energy indicators for further refining the original set of indicators. The final set of energy indicators in this report builds on their cumulative experience. By consensus, the original set of 41 indicators was reduced to the 30 EISD that constitute the final core set of energy indicators presented in this report. A number of

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2 IAEA/IEA, 2001. *Indicators for Sustainable Energy Development*, presented at the 9th Session of the CSD, New York, April 2001. Vienna, Austria: International Atomic Energy Agency (IAEA)/International Energy Agency (IEA).

indicators were redefined and merged; others were classified as auxiliary indicators. Although the original framework followed the DSR framework, the package was modified to emphasize main themes and sub-themes following the same approach currently used by the CSD on the ISD.

The 30 EISD presented here are classified according to the three major dimensions of sustainable development: social (4 indicators), economic (16 indicators) and environmental (10 indicators). Each group is divided into themes and sub-themes. The indicators in the EISD core set are thus consistent with and supplementary to the CSD indicators as published by UNDESA in 2001.[3] Moreover, this interagency report reflects a consensus of leading experts on definitions, guidelines and methodologies for the development and worldwide use of energy indicators for sustainable development.

2.3.2 International Energy Agency (IEA)

The IEA project on energy indicators was established in 1996. The analytical framework and data developed under this project have become important tools for IEA analysis of energy-use developments. The focus of the energy indicator project is to assist IEA Member countries in analysing factors behind changes in energy use and emissions of carbon dioxide (CO_2). The indicators (and the associated databases) help to reveal key couplings between energy use, energy prices and economic activity. This insight is crucial when assessing and monitoring past and present energy efficiency policies and for designing effective future actions. Data developed for the IEA indicator project are also used for other IEA analytic activities, such as the *World Energy Outlook* publication and several energy efficiency and energy technology projects within the IEA Secretariat.

An important aim of the IEA's work on indicators is to increase the transparency and quality of energy-use data. This provides a better basis for meaningful comparisons of energy and emission developments across countries, as well as a tool to measure progress in emission reductions and efficiency improvements within individual countries over time. The IEA has worked with Member countries and with the European Community to ensure the official and consistent collection of data. A database with energy indicator data for most IEA countries has recently been completed. The IEA has published several reports on energy indicators, and in 2004 the IEA released a publication highlighting findings of its work on indicators.[4] The IEA is also assisting non–Organisation for Economic Co-operation and Development (OECD) countries to improve their energy statistics and to establish energy indicators. This includes work with international organizations such as the Energy Charter Secretariat, Eurostat, the Asia Pacific Energy Research Centre (APERC) and the IAEA.

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3 UNDESA, 2001. *Indicators of Sustainable Development: Guidelines and Methodologies*, 2nd edition, September. New York, NY, USA: United Nations Department of Economic and Social Affairs.

4 IEA, 2004. *Oil Crises and Climate Challenges: 30 Years of Energy Use in IEA Countries*. Paris, France: International Energy Agency.

In the 2004 edition of the *World Energy Outlook,*[5] the IEA introduced an energy development index (EDI) to better understand the role that energy plays in human development. The index is intended to be used as a simple composite measure of a country or region's progress in its transition to modern fuels and of the degree of maturity of its energy end use. The EDI seeks to capture the quality of energy services as well as their quantity and can be used to assess the need for policies to promote the use of modern fuels and to stimulate investment in energy infrastructure in each region. It is calculated in such a way as to mirror the Human Development Index (HDI) of the United Nations Development Programme (UNDP).

2.3.3 Eurostat

Eurostat has collaborated with the IEA on energy-data collection for more than 25 years, and more recently has collaborated on indicator development. As in most IEA Member countries, since the oil crises of the 1970s, energy policy in the European Union (EU) has traditionally concentrated on security and diversity of supply, energy efficiency, prices and competitiveness. At the European Council[6] meeting in Cardiff in 1998, the principle of integrating environmental concerns into broader policy was introduced, with a particular emphasis on energy. Minimizing damage to the environment became of fundamental importance to the EU's sustainable energy policy. This 'Cardiff Process' emphasized the need for indicators to measure progress and so raised the profile of indicator work. Eurostat publishes annually, in pocketbook format, integration indicators for energy based on data collected by Eurostat and the EEA.

In June 2001, the European Council in Gothenburg integrated the Cardiff Process into a new, wider EU Sustainable Development Strategy (SDS). The SDS is based on the principle that the economic, social and environmental effects of all policies should be considered in a coordinated manner in all decision making.

Energy issues are addressed under several of the themes of the SDS. On climate change, the SDS aims to reduce greenhouse gas (GHG) emissions by increasing the use of renewable forms of energy. It addresses public health, where air pollution from the burning of fossil fuels is an important issue, and it addresses transport. Energy is also of primary importance for the EU's commitments following the WSSD and the JPOI, for sustainable production and consumption, and for global partnership and good governance.

Following the adoption of the EU SDS, the EU's Statistical Programme Committee[7] set up a Task Force on sustainable development indicators to promote a common approach for the European Statistical System. This Task Force is chaired by the 'Environment and Sustainable Development' unit of Eurostat and is composed of experts from Member States, European Free Trade Area countries, various Commission Directorates-General and international organizations.[8]

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5 IEA, 2004. *World Energy Outlook.* Paris, France: International Energy Agency.

6 The European Council is made up of the heads of state of the EU Member States and meets at least every six months.

7 The Statistical Programme Committee is composed of the general-directors of the statistical institutions of EU Member States.

8 For more information, see http://forum.europa.eu.int/Public/irc/dsis/susdevind/home.

2.3.4 European Environment Agency (EEA)

The EEA is the EU body dedicated to providing sound, independent information on the environment. It is a main information source for those involved in developing, adopting, implementing and evaluating environmental policy, and for the general public.

Indicators are an important tool in the EEA's work for assessing progress towards environmental protection and sustainable development. The EEA's indicator work covers the environmental aspect of sustainable development and is based on the so-called DPSIR assessment framework (Driving forces, Pressures, State of the environment, Impacts, and societal Responses).

The EEA has developed a set of about 25 indicators for energy and environment that are updated regularly. In line with the EEA's mandate, these indicators have more of an environmental emphasis than those of the IEA or Eurostat[9] and, taken together, allow assessment of progress towards environmental integration in Europe by energy sector. The indicators describe the development of the sector in Europe and implications for the environment and related policy actions. The indicators cover not only the current situation, but also trends and prospects; most importantly, they point to the conditions for change that are needed for progress towards a more sustainable energy policy that benefits the environment.

[9] More information on the work of the EEA on energy and environment indicators is available at http://themes.eea.eu.int/Sectors_and_activities/energy, including the EU's first report (http://reports.eea.eu.int/environmental_issue_report_2002_31/en).

3. ENERGY INDICATORS FOR SUSTAINABLE DEVELOPMENT

The indicators in the Energy Indicators for Sustainable Development (EISD) core set are discussed in this chapter according to dimensions, themes and sub-themes following the same conceptual framework used by the United Nations Commission on Sustainable Development (CSD). Table 3.1 lists the indicators that make up the EISD core set. There are 30 indicators, classified into three dimensions (social, economic and environmental). These are further classified into 7 themes and 19 sub-themes. Note that some indicators can be classified in more than one dimension, theme or sub-theme, given the numerous interlinkages among these categories. Also, each indicator might represent a group of related indicators needed to assess a particular issue.

Table 3.1: List of Energy Indicators for Sustainable Development

Social				
Theme	**Sub-theme**	**Energy Indicator**		**Components**
Equity	Accessibility	SOC1	Share of households (or population) without electricity or commercial energy, or heavily dependent on non-commercial energy	– Households (or population) without electricity or commercial energy, or heavily dependent on non-commercial energy – Total number of households or population
	Affordability	SOC2	Share of household income spent on fuel and electricity	– Household income spent on fuel and electricity – Household income (total and poorest 20% of population)
	Disparities	SOC3	Household energy use for each income group and corresponding fuel mix	– Energy use per household for each income group (quintiles) – Household income for each income group (quintiles) – Corresponding fuel mix for each income group (quintiles)
Health	Safety	SOC4	Accident fatalities per energy produced by fuel chain	– Annual fatalities by fuel chain – Annual energy produced

Economic				
Theme	**Sub-theme**	**Energy Indicator**		**Components**
Use and Production Patterns	Overall Use	ECO1	Energy use per capita	– Energy use (total primary energy supply, total final consumption and electricity use) – Total population
	Overall Productivity	ECO2	Energy use per unit of GDP	– Energy use (total primary energy supply, total final consumption and electricity use) – GDP
	Supply Efficiency	ECO3	Efficiency of energy conversion and distribution	– Losses in transformation systems including losses in electricity generation, transmission and distribution
	Production	ECO4	Reserves-to-production ratio	– Proven recoverable reserves – Total energy production
		ECO5	Resources-to-production ratio	– Total estimated resources – Total energy production
	End Use	ECO6	Industrial energy intensities	– Energy use in industrial sector and by manufacturing branch – Corresponding value added
		ECO7	Agricultural energy intensities	– Energy use in agricultural sector – Corresponding value added
		ECO8	Service/ commercial energy intensities	– Energy use in service/ commercial sector – Corresponding value added
		ECO9	Household energy intensities	– Energy use in households and by key end use – Number of households, floor area, persons per household, appliance ownership
		ECO10	Transport energy intensities	– Energy use in passenger travel and freight sectors and by mode – Passenger-km travel and tonne-km freight and by mode

Economic				
Theme	**Sub-theme**	**Energy Indicator**		**Components**
	Diversification (Fuel Mix)	ECO11	Fuel shares in energy and electricity	– Primary energy supply and final consumption, electricity generation and generating capacity by fuel type – Total primary energy supply, total final consumption, total electricity generation and total generating capacity
		ECO12	Non-carbon energy share in energy and electricity	– Primary supply, electricity generation and generating capacity by non-carbon energy – Total primary energy supply, total electricity generation and total generating capacity
		ECO13	Renewable energy share in energy and electricity	– Primary energy supply, final consumption and electricity generation and generating capacity by renewable energy – Total primary energy supply, total final consumption, total electricity generation and total generating capacity
	Prices	ECO14	End-use energy prices by fuel and by sector	– Energy prices (with and without tax/subsidy)
Security	Imports	ECO15	Net energy import dependency	– Energy imports – Total primary energy supply
	Strategic Fuel Stocks	ECO16	Stocks of critical fuels per corresponding fuel consumption	– Stocks of critical fuel (e.g. oil, gas, etc.) – Critical fuel consumption

Environmental				
Theme	**Sub-theme**	**Energy Indicator**		**Components**
Atmosphere	Climate Change	ENV1	GHG emissions from energy production and use per capita and per unit of GDP	– GHG emissions from energy production and use – Population and GDP
	Air Quality	ENV2	Ambient concentrations of air pollutants in urban areas	– Concentrations of pollutants in air
		ENV3	Air pollutant emissions from energy systems	– Air pollutant emissions
Water	Water Quality	ENV4	Contaminant discharges in liquid effluents from energy systems including oil discharges	– Contaminant discharges in liquid effluents
Land	Soil Quality	ENV5	Soil area where acidification exceeds critical load	– Affected soil area – Critical load
	Forest	ENV6	Rate of deforestation attributed to energy use	– Forest area at two different times – Biomass utilization
	Solid Waste Generation and Management	ENV7	Ratio of solid waste generation to units of energy produced	– Amount of solid waste – Energy produced
		ENV8	Ratio of solid waste properly disposed of to total generated solid waste	– Amount of solid waste properly disposed of – Total amount of solid waste
		ENV9	Ratio of solid radioactive waste to units of energy produced	– Amount of radioactive waste (cumulative for a selected period of time) – Energy produced

Environmental				
Theme	**Sub-theme**	**Energy Indicator**		**Components**
		ENV10	Ratio of solid radioactive waste awaiting disposal to total generated solid radioactive waste	– Amount of radioactive waste awaiting disposal – Total volume of radioactive waste

3.1 The Indicators as a Measure of Progress

Some of these indicators are unequivocal measures of progress; they clearly distinguish between desirable and undesirable trends. Most of the social and environmental indicators fall into this category, including such indicators as SOC4 (accident fatalities), ENV3 (air pollutant emissions from energy systems) and ENV6 (rate of deforestation attributed to energy use). However, some of these indicators also must be taken in context; for example, depending on the development choices made, there may be a temporary rise in undesirable effects until a higher level of development is achieved, representing a larger benefit that could outweigh the interim disadvantages. Another example is when the availability of commercial fuels — for example, kerosene — in developing countries increases the share of a household's income spent on energy (SOC2). This may not indicate a negative development from a social perspective, since the collection of non-commercial fuelwood often involves significant losses of productive time and the burning of the wood often has important health consequences.

Other indicators are not designed to distinguish between 'good' and 'bad' but rather describe and give an indication of an aspect of energy use. Most of the economic indicators fall into this category. They include ECO1 (energy use per capita) and ECO3 (efficiency of energy conversion and distribution). Energy use per capita might be low in a given country because that country is very poor or because there is high energy efficiency and the economy is based on services rather than on heavy industry. The ratio of final to primary energy might be high because the country has a rudimentary energy system where primary and final energy are the same, or it might be high because the country has an advanced economy and efficient energy transformation.

The indicators need to be read in the context of each country's economy and energy resources. An economy that is dominated by primary extraction and processing will have relatively high energy use per unit of gross domestic product (GDP) no matter how efficient it is. This does not mean that the country should abandon development of its resource base.

Structural changes to the economy must also be taken into account. For example, building a large, modern aluminium smelter in a country that previously relied on subsistence farming and foreign aid would result in a large increase in the ECO6 indicator (industrial energy intensities), but would also generate export revenues and hence improve income levels.

Nonetheless, the indicators taken together and in context, allowing for inherent differences between countries, give a good picture of a country's energy system. As the indicators change over time, they will be good markers of progress and underlying changes. This will guide policy and help guide decisions on investments in energy, pollution control and industry.

Finally, the use of indicators can help answer questions about external costs, which are often difficult to quantify. Energy markets can and do accommodate the internalization of some of the 'external costs' of energy through more or less efficient responses to more or less correct economic and regulatory incentives. However, some external costs are difficult to internalize, with the result that they will be borne by society. Such externalities include ill health, environmental damage and decline in property values caused by oil refineries, power lines and other energy facilities.

What cost is placed on a tonne of nitrous oxides emitted from a gas or coal power station, a tonne of radioactive waste from a nuclear power station or a landscape disrupted by wind turbines? What penalties or subsidies[1] does one give to each energy technology? By quantifying energy intensity, accidents per unit of energy and environmental consequences per unit of energy, indicators can permit comparative assessment of alternatives and strategies, and help policymakers to decide on appropriate measures, including penalties or subsidies, to promote efficient and sustainable energy development. Indicators to reflect the extent of internalization of external costs are being developed and may be incorporated into the EISD in due time.

3.2 Dimensions of Sustainable Development

Sustainable development is essentially about improving quality of life in a way that can be sustained, economically and environmentally, over the long term supported by the institutional structure of the country. For this reason, sustainable development addresses four major dimensions: social, economic, environmental and institutional. The indicators are divided into three dimensions: social, economic and environmental; institutional questions are largely considered to be responses and not readily quantified as indicators. Although a sound institutional structure is essential for an efficient and reliable energy system, indicators to reflect this institutional dimension are still being developed and may be incorporated into the EISD at a later stage.

3.2.1 Social Dimension

Availability of energy has a direct impact on poverty, employment opportunities, education, demographic transition, indoor pollution and health, and has gender- and age-related implications. In rich countries, energy for lighting, heating and cooking is available at the flip of a switch. The energy is clean, safe, reliable and affordable. In poor countries, up to six hours a day is required to collect wood and dung for cooking and heating, and this task is usually done by women, who could be otherwise engaged in more productive activities. In areas where coal, charcoal and/or paraffin are commercially available, these fuels take up a large portion of the monthly household

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[1] EEA, 2004. *Energy Subsidies in the European Union: A Brief Overview.* Technical report 1/2004. Copenhagen, Denmark: European Environment Agency.

income. Inadequate equipment and ventilation means that these fuels, burned inside the house, cause a high toll of disease and death through air pollution and fires.

This example serves to illustrate the two themes of the social dimension: Equity and Health. Social equity is one of the principal values underlying sustainable development, involving the degree of fairness and inclusiveness with which energy resources are distributed, energy systems are made accessible and pricing schemes are formulated to ensure affordability. Energy should be available to all at a fair price.

The Equity indicators have the sub-themes of Accessibility, Affordability and Disparities. Because of a lack of access to modern energy (for example, by not being connected to the electricity grid), poor households not only spend a larger portion of their income on energy than do the rich, but they often have to pay more in absolute terms per unit of useful energy. A household in an African township often has to pay more for the coal or paraffin needed to cook a meal than one in a European city pays for the electricity to do the same amount of cooking. The lack of electricity limits work opportunities and productivity, as without electricity it is only possible to use the simplest tools and equipment. It also usually means, among other limitations, inadequate illumination, limited telecommunications and no refrigeration.

Limited income (limited affordability) may force households to use traditional fuel and inefficient technologies, and the time needed to find and collect fuelwood is time that cannot be spent cultivating fields or otherwise working. The poor usually have to spend a large share of their income on indispensable energy fuels such as those required for services like cooking and heating.

There may be disparities in access or affordability between regions and between income groups within a region. Disparities within a country or between countries may result from highly uneven income distributions, inadequate energy transport and distribution networks, and major geographical differences among regions. In many countries the large disparity in household incomes and energy affordability is a major problem in low-income neighbourhoods in both urban and rural areas, even if commercial energy services are available.

The Accessibility and Affordability indicators are clear markers of progress towards development. They also mark an improvement in the situation of women, since it is invariably women who bear the burden of fuel collection in poor countries. With easily obtainable commercial energy, these women will have more time to improve their lot and that of their children.

The use of energy should not damage human health, but rather should improve it by improving living conditions. Yet the production of energy has the potential to cause injury or disease through pollution generation or accidents. A social goal is to reduce or eliminate these negative impacts. The Health indicators have the sub-theme of Safety, which covers accident fatalities caused by the extraction, conversion, transmission/distribution and use of energy. Oil rigs and, particularly, coal mines are subject to accidents that injure, maim or kill people. Oil refineries and power stations may release emissions into the air that cause lung or respiratory diseases. However, per unit of energy, the toll from energy use in households is often much higher. In squatter camps or informal settlements, for example, fires that kill or maim people are regular occurrences. In households that burn coal, wood and kerosene for cooking and heating in traditional fireplaces and stoves, there are high levels of respiratory diseases, especially in children.

3.2.2 Economic Dimension

Modern economies depend on a reliable and adequate energy supply, and developing countries need to secure this as a prerequisite for industrialization. All sectors of the economy — residential, commercial, transport, service and agriculture — demand modern energy services. These services in turn foster economic and social development at the local level by raising productivity and enabling local income generation. Energy supply affects jobs, productivity and development. Electricity is the dominant form of energy for communications, information technology, manufacturing and services.

The economic indicators have two themes: Use and Production Patterns, and Security. The first has the sub-themes of Overall Use, Overall Productivity, Supply Efficiency, Production, End Use, Diversification (Fuel Mix) and Prices. The second has the sub-themes of Imports and Strategic Fuel Stocks.

ECO2 (energy use per unit of GDP) is a marker of aggregate energy intensity. Much attention is paid to efficiencies and aggregated and disaggregated intensities in defining the sustainability of consumption trends. However, caution is warranted in the interpretation of these indicators. A country whose economy is based on banking and trading will use less energy per unit of GDP than one whose economy is based on steel making and ore processing. By taking the structure of the economy into account, these indicators can monitor changes in energy efficiency, which in turn may be linked to changes in technologies, fuel mix or consumer preferences or behaviour.

ECO3 (efficiency of energy conversion and distribution) monitors energy efficiency in transformation processes such as power stations. Again, it is essential to allow for the nature of the economy. Neolithic communities would all have had a ratio of 1.0, since they had no transformation processes at all. The Production indicators look at the energy being used compared with the indigenous energy resources.

There are indicators for energy intensity in individual sectors. Since they are sector specific, they can be good benchmarks of energy efficiency, economic structure and the vintage of plants and equipment. However, changes measured by value added are subject to world commodity prices and currency fluctuations in trade-dependent sectors that can change the indicators dramatically but have nothing to do with real changes in efficiency or practice. Therefore, such indicators must be interpreted cautiously.

ECO11, which gives the proportions of energy from different energy fuels, provides a useful picture of the primary energy supply mix and shows the extent of energy diversification.

The prices of end-use energy by fuel and sector (ECO14) have obvious economic importance. Efficient energy pricing is key to efficient energy supply and use, and socially efficient levels of pollution abatement. Energy prices and related subsidies and taxes can encourage efficiency of energy use or improve access levels, or they can generate inefficiencies in the supply, distribution and use of energy. While relatively high prices for commercial fuels can be seen as a barrier to access, prices that cover the cost of delivery are necessary for attracting investment in a secure and reliable energy supply.

Addressing energy security is one of the major objectives in the sustainable development criteria of many countries. Interruptions of energy supply can cause serious financial and economic losses. To support the goals of sustainable development, energy must be available at all times, in sufficient quantities and at affordable prices. Secure energy supplies are essential to maintaining economic activity and to providing reliable energy services to society. The monitoring of trends of net energy imports and the availability of appropriate stocks of critical fuels are important for assessing energy security.

3.2.3 Environmental Dimension

The production, distribution and use of energy create pressures on the environment in the household, workplace and city, and at the national, regional and global levels. The environmental impacts can depend greatly on how energy is produced and used, the fuel mix, the structure of the energy systems and related energy regulatory actions and pricing structures. Gaseous emissions from the burning of fossil fuels pollute the atmosphere. Large hydropower dams cause silting. Both the coal and nuclear fuel cycles emit some radiation and generate waste. Wind turbines can spoil pristine countryside. And gathering firewood can lead to deforestation and desertification.

The Environmental indicators are divided into three themes: Atmosphere, Water and Land.

The sub-themes on the Atmosphere are Climate Change and Air Quality. Priority issues include acidification, the formation of tropospheric ozone and emissions of other pollutants affecting urban air quality. Greenhouse gas (GHG) emissions are central to the debate on whether humankind is changing the climate for the worse. Air pollutants of major concern include sulphur oxides, nitrogen oxides, carbon monoxide and particulates (the last two being particularly important for indoor air pollution). These pollutants can damage human health, leading to respiratory problems, cancer, etc.

Water and land quality are other important sub-themes of the environmental dimension. Land is more than just physical space and surface topography; it is in itself an important natural resource, consisting of soil and water, essential for growing food and providing habitat for diverse plant and animal communities. Energy activities may result in land degradation and acidification that affect the quality of water and agricultural productivity. The use of wood as (non-commercial) fuel may result in deforestation, which in some countries has led to erosion and soil loss. Some countries have long histories of steady deforestation. Although environmental legislation is now in place in many countries to avoid further land degradation, the damage still affects significant areas.

Land is also affected by energy transformation processes that often produce solid wastes, including radioactive wastes, which require adequate disposal. Water quality is affected by the discharge of contaminants in liquid effluents from energy systems, particularly from the mining of energy resources.

3.2.4 Institutional Dimension

The EISD do not yet include institutional indicators. These indicators are the most difficult to define for two reasons. First, they tend to address issues that are, by nature, difficult to measure in quantitative terms. Many of these issues relate to the future and require dynamic analysis based on projections of energy production, use and investment. Second, the variables measured by institutional indicators tend to be structural or policy responses to sustainable development needs.

For example, institutional indicators might help to measure not only the existence but also the effectiveness of a national sustainable energy development strategy or plan, energy statistical capacity and analytical capabilities, or the adequacy and effectiveness of investments in capacity building, education or research and development. Institutional indicators could also help to monitor progress towards appropriate and effective legislative, regulatory and enforcement institutions for energy systems.

Infrastructure is the backbone of any national energy system. Countries need to monitor the state of their major energy infrastructures to ensure a sustainable energy future. Many countries now depend on major energy infrastructures that are obsolete, inefficient, insufficient or environmentally unacceptable.

3.3 Accommodating National Sustainability and Development Priorities

Some caveats are in order about the use of the EISD and their interpretation for monitoring progress towards sustainable energy development. Since the publication of the Brundtland Report, countries have begun to define their own sustainable development objectives and priorities, reflecting national resources and needs, aspirations, and social and economic conditions. Sustainable development strategies must therefore be structured to accommodate a wide range of definitions of what desirable sustainable development can encompass, and monitoring the success of such strategies through indicators must also avoid rigid definitions or judgements about what is universally desirable and necessary.

For example, it is possible for an economy to be sustainable without developing. This was true of hunter-gatherer groups living twenty thousand years ago. It is also possible for a country to develop without its development being sustainable. This would be true of a country completely dependent on a lucrative and highly effective fishing industry that generates high income levels, thus enabling investment in schools, hospitals, art galleries and welfare services, but that also exhausts the fish stocks. This country would have achieved a degree of development, but that development would not be sustainable since it is destroying the country's source of income.

However, it is also true that the depletion of resources does not necessarily imply unsustainable development. By definition, if an energy source is not renewable, any use of it is irreversible. But this does not mean it should never be used. Consider a country with a natural gas field that uses all of the gas in a way calculated to bring in funds to build up its economy and technology, and then moves on to another form of energy — for example, renewables or imported fuels. This may represent sustainable development. The depletion of the gas field by one generation does not necessarily jeopardize the energy supply for future generations.

Paradoxically, the economic and environmental crises of depletion in the past have all come from the exhaustion of renewable resources — overfishing, overgrazing, cutting down too many trees, etc. This highlights the importance of not using renewable resources at a rate faster than their natural replenishment rates.

The indicators, with one possible exception, do not individually distinguish between a focus on sustainability or on development. The possible exception is SOC1 (share of households without electricity or commercial energy). This is clearly an indicator of development only and not sustainability. The rest of the indicators could mark either. However, used together and in the context of a country's individual circumstances, they can be used to show progress towards sustainable development and attainment of the goals defined by the country's particular sustainable development strategy.

3.4 Establishing Links and Causality

If indicators are to be used to guide policymaking and strategic decisions, then they must provide some notion of where to apply policy pressure and where to initiate changes that can bring desired results. Establishing links and some idea of causality is thus an important feature of policy monitoring with indicators. Seeing trends without understanding how to affect them is not useful for strategic development.

A complete understanding of how each individual economic activity influences all others and fits into the whole is not yet in reach. Nonetheless, one can establish useful general rules of cause and effect to analyse economies and guide policymaking. The indicators can help us understand some of the effects that energy production and use have on the economy and the environment. By linking these indicators and monitoring changes in their values, one should be able to see the effects that shifts in energy production or use have on the economy, society and the environment.

In general, a cause–effect framework allows policymakers to track pathways and subsidiary effects from the point of a policy's implementation to its impacts in order to discern linkages among energy and to target policies more specifically.

A model of cause and effect was initially designed to identify and categorize the EISD using a driving force, state and response (DSR) framework. Similar models are used by international organizations such as the Organisation for Economic Co-operation and Development (OECD), the International Energy Agency (IEA), the United Nations Department of Economic and Social Affairs (UNDESA), Eurostat and the European Environment Agency (EEA). These include, for example, the pressure-state-response (PSR) model developed by the OECD for categorizing the nature of different environmental indicators and the DPSIR (Driving forces, Pressures, State of the environment, Impacts, and societal Responses) framework developed by the EEA.

The PSR framework describes indicators for environmental *pressures* as 'direct' and 'indirect' pressures exerted on the environment. These indirect pressures are called driving forces in other models. The indicators for the environmental *state* relate to environmental quality and the quality and quantity of natural resources. The indicators for societal *responses* measure how society responds to environmental concerns through individual and collective actions and reactions.[2]

In the DPSIR framework, the *driving forces* are the causes underlying the problem; *pressures* are the pollutant releases into the environment; *state* is the condition of the environment; *impact* is the effects of environmental degradation; and *responses* are the measures taken to reduce the drivers and pressures on the environment or to mitigate the impact and effect on the state of the environment. The DPSIR framework is used by the EEA to categorize its environmental indicators.[3]

As previously noted, the CSD has abandoned the use of the driving force, state and response (DSR)-type categorization of indicators as being unwieldy and subject to definitional difficulties. Consequently, and following the same approach currently used by the CSD on the Indicators of Sustainable Development (ISD), the EISD are now simply categorized according to the theme and sub-theme framework. The theme framework emphasizes policy issues and is useful in discerning correlations among themes, defining sustainable development goals and basic societal needs. In addition, the theme framework has proved to be easier to understand and implement at the country level. However, when interpreting the indicators, care must be taken in attributing causality, because the indicators can sometimes show trends that are similar but not linked.

3.5 Data and Statistics for the Indicators

For indicators to be reliable and useful tools, they must have a solid base in valid and consistent statistical data. Obtaining reliable, accurate, comprehensive, recent data requires considerable effort. The indicators have been structured to make this task as straightforward as possible, and the methodology sheets in this report are designed to facilitate the process. Introducing the EISD at the national level will necessarily be an improvement in statistical arrangements and analytical capabilities.

The indicators should also help to clarify for each country where its priorities lie. This will help it to concentrate its statistical abilities in the most appropriate areas. Since the energy indicators mark social, economic and environmental trends, they will be useful to the relevant government departments, which have their own databases. This should help to improve the databases and coordinate the statistical services of these departments.

3.6 Auxiliary Statistics/Indicators

The construction and interpretation of energy indicators require the use of a number of auxiliary statistics that measure, for example, demographics, wealth, economic development, transport, urbanization, etc. Some of these statistics include

- Population.
- GDP per capita.

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2 OECD, 2000. Environmental Performance Indicators: OECD Overview, in *Towards Sustainable Development: Indicators to Measure Progress*, Proceedings of the OECD Rome Conference. Paris, France: Organisation for Economic Co-operation and Development.

3 EEA, 2002. *Energy and Environment in the European Union*. Environmental issue report no. 31. Copenhagen, Denmark: European Environment Agency.

- Shares of sectors in GDP value added.
- Distance travelled per capita.
- Freight transport activity.
- Floor area per capita.
- Manufacturing value added for selected industries.
- Income inequality.

These statistics may serve as indispensable components for the formulation of some of the indicators in the EISD core set, or as complements to their analysis and interpretation.

3.7 Methodology Sheets

A complete description of each of the indicators in the EISD core set is provided in the corresponding methodology sheets in Chapter 5. These sheets have been designed to provide the user with all the information needed to develop the indicators. They contain the following:

- Basic information on the indicator, including its definition and unit of measurement, alternative definitions, auxiliary data or indicators needed for its development and the relevant Agenda 21 chapter.
- Policy relevance, including purpose and relevance to sustainable development; international conventions, agreements, targets or recommended standards, if applicable; and linkage to other related indicators.
- Methodological description, including underlying definitions and concepts, measuring methods, limitations and alternative definitions.
- Assessment of data, including the data needed to compile the indicator, national and international data availability and sources, and related publications that include similar indicators or related issues.
- References.

A conscious effort has been made to use a consistent format to frame the contents of the methodology sheets. The sheets follow the format used by the CSD in the methodology sheets of its overall ISD core set, making this report consistent with and an extension (at the energy-sector level) of the corresponding report by UNDESA.[4]

The methodology sheets are designed to help countries develop indicators that are relevant to their energy policies and programmes for sustainable development. The methodology sheets represent a starting point for the process of developing energy indicators and are open for refinement and amendment.

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[4] The methodology sheets for the UNDESA set of ISD are available at http://www.un.org/esa/ustdev/natlinfo/indicators/isdms2001/

4. SELECTING AND USING ENERGY INDICATORS

The information in this section is intended to help countries in selecting and using energy indicators and in setting up their own national energy indicator programmes.

The relative importance of different indicators for sustainable energy development will vary from country to country, depending on country-specific conditions, national energy priorities, and sustainability and development criteria and objectives. Every country has its own special economic circumstances and geography, its own range of energy resources and its own expertise and priorities. Therefore, each country will have its own way of using the Energy Indicators for Sustainable Development (EISD). The implementation process will depend on national policy goals, existing statistical capabilities and expertise, and the availability and quality of energy and other relevant data. Each country can make the most appropriate allocation of people and resources for the development of the EISD so as to obtain the greatest benefit at an affordable cost.

4.1 Information Gathering

Countries might need to evaluate their statistics programmes and data collection capabilities and the range and quality of their energy data. This might include a review of the agencies that collect and compile statistics, and an assessment of the energy data already being collected. The data required cover energy, demographics, economics and the environment for the country as a whole and within specific economic sectors (agricultural, residential, commercial, industrial and transport). Organizations for collecting statistics include central statistical offices, government departments, reserve banks, revenues offices, research institutes and non-governmental organizations.

To evaluate the energy statistical capacity and data availability that will support the implementation of the EISD core set, it is recommended that countries consider the following actions:

- Determine which organizations are specifically responsible for each type of data collection and statistical analysis.
- Review and ascertain the scope, quality and reliability of the basic data. This assessment might include data availability, collection frequency, time periods, quality, reliability and relevance. The statistics used in the EISD need to be consistent in form and definition. The units should be standardized throughout.
- Determine whether energy indicators are already being used and, if so, which ones. It is also necessary to determine whether these indicators are consonant with, or can be complementary or supplemental to, the EISD.

This review, and assembling the required data, could lead to several hurdles. Data may be difficult to find or may not exist. The responsibility for maintaining and monitoring energy databases and related activities (including data collection, compilation and analysis) is likely to reside in a number of institutions, such as national statistical offices, ministries of energy, economy, trade or industry, and environment and national energy commissions. The data required by one organization might be collected by another, or there might be duplication of efforts or jurisdictional concerns. Therefore, a coordinating mechanism for the development and implementation of EISD might be needed to facilitate coordinated activities among major players.

It might, therefore, be desirable to set up a body to liaise with all of the relevant organizations in the country and to coordinate their activities with the EISD effort. This national coordinating mechanism could take the form of a working group or committee based on existing institutional arrangements where possible, using the experience and expertise of extant organizations and making use of the widest possible consultation and participation of all stakeholders involved. The mechanism should be flexible and transparent. Such an effort should help to avoid duplication, inconsistencies and unnecessary data collection. It should also facilitate the incorporation of the analysis of these indicators into a broader range of ongoing statistical programmes.

Countries might need to invest in improving their energy and other related statistics to take full advantage of the EISD. This includes improved data collection, monitoring and analysis at the national and regional levels. Missing data might need to be collected or derived. Data compilation and interpretation might need to be improved. This will require training and an assessment of the resources involved, including the cost of new data collection.

4.2 Statistical Considerations: Time Series, Missing Data and Interpretation in Context

Each indicator should be seen in the context of a given country's individual circumstances. These include the structure of the economy, changing energy technologies and new energy options. Transitions or shifts — such as if the country changes from subsistence farming to commercial farming, if it changes its electricity supply from small diesel power stations to large hydropower plants, if it moves from heavy manufacturing to information technology, or if it discovers a large gas field — can substantially change the value of an EISD. The analysts must take these kinds of changes into account when interpreting whether an indicator shows progress towards sustainable development or not. This might mean giving the indicators different relative importance with changing circumstances.

4.2.1. Time Series

Energy indicators are necessary to evaluate past developments, assess the status of the energy system, define potential targets and measure progress. Therefore, the snapshot of information given by the set of indicators at any moment is of limited use. What is important is how the indicators change over time. It is therefore essential to record time series of each indicator in a consistent manner.

Time series data are thus indispensable in the evaluation of the effectiveness of policies in the long run. They permit an evaluation of how a country got to where it is and which policies are responsible for current trends, whether the country is where it wants to be and whether it will achieve its proposed targets under proposed policy choices. The extension of the analysis into the future through the use of scenarios developed with modelling tools permits a comparative assessment of different policy and strategic paths, and more comprehensive monitoring and analysis of sustainable development trends. To foster an effective debate about national sustainable energy development policy, the government might wish to disseminate the results of such trend analysis.

4.2.2. Missing Data

Some relevant data might not exist at all, some might be difficult to find and some might be scattered around in disparate institutions and government departments. There might be duplication in data collection, or data might be collected in different units and on different bases.

It might not be possible to fill in gaps in historical data by 're-collection' of the data, and it might not be possible to collect all future data required. Some of the missing data could be estimated by interpolating between the known data. In some cases, proxies could be used to approximate missing data. For instance, if there were no data on deforestation specifically resulting from energy use (ENV6), one might be able to estimate this indicator from the amount of non-commercial fuel used and the total deforestation resulting from all purposes. Alternatively, data from other countries might be scaled or adapted. A certain degree of creativity wedded to topical and statistical expertise and understanding is implied in this exercise.

4.2.3. Interpretation in Context

Most of the social and environmental indicators are unambiguous markers of progress. For example, if ambient concentrations of air pollutants in urban areas (ENV2) show lower values than were previously measured, then this is certainly a sign of progress and an indication that the policies in this area most likely have contributed to this.

However, this is not necessarily the case with the economic indicators. For example, if agricultural energy intensity (ECO7) increases, this might be because of a higher degree of mechanization or because of a structural change in agriculture, such as a change from one crop to another that requires more energy for its growing, harvesting and processing. In these cases, changes in the indicators must be considered in the context of the country's specific conditions. So used, however, they show the effects of policy decisions and are useful for evaluating such decisions and designing future policy.

The analysis and interpretation of the EISD need to be performed within the context of each country's energy and sustainable development priorities. As each country is unique, the results from one country should not necessarily be taken as a standard for comparison with another country facing different conditions.

The EISD represent a quantitative tool for monitoring progress and for defining strategies towards a more sustainable energy future. There are a number of issues that are difficult to quantify or are more qualitative by nature but that need be considered in decision-making processes and in the formulation of major energy policies. Many of these non-quantifiable aspects are within the institutional dimension of sustainable development. Therefore, the results of analysis with the EISD tool need to be put into a larger policy perspective for effective decision making.

4.3. Priorities and Approaches for Individual Countries

The EISD as presented in this report constitute a recommended rather than a complete core set of energy indicators. Since every country is unique, each will have its own approach to the EISD and will use them according to its own priorities. Each will decide which of the indicators within the recommended EISD core set are relevant to its needs and may even develop other indicators for its own special circumstances of energy supply and demand.

One approach that might be considered includes the following steps:

- Identify major energy priority areas. This might already have been done in national energy plans or programmes. These national plans could constitute a possible point of departure for an initial application of EISD. Known vulnerabilities in the national energy structure or known financial, environmental or social pressures related to energy can inspire ideas on the critical areas to cover.
- Select the indicators from the EISD core set that are relevant for addressing these priority areas. If necessary, define and structure new indicators. Determine specifically how progress in specified variables and factors would be monitored using EISD.
- Determine what data are needed to cover the priority areas. Review available data to assess the adequacy of statistics to cover the priority areas. If needed, collect additional statistics or establish proxy data.
- Compile data in time series for each selected EISD.
- Analyse the data and their implications. Evaluate progress made in the relevant priority area. Assess the effectiveness of past and present energy policies. Test interpretations and conclusions for sensitivities, for false assumptions about linkages and causality, or for biases reflecting value judgements.
- Consider different energy policies for the future and look at their possible effects by using energy models for different scenarios. In this way, a country may learn the lessons of the past while exploring options for the future.
- If possible, use alternative scenarios developed with modelling tools and projected time series to explore future policy and growth trajectories. The EISD need to be linked to expected or desired energy futures. Sustainability implies a forward-looking approach and not just a look at the past and the present.

5. METHODOLOGY SHEETS

This chapter presents the methodology sheets for the Energy Indicators for Sustainable Development (EISD), grouped according to the social, economic and environmental dimensions.

Definitions for a number of the energy, economic and environmental terms used in this report are given in Annex 1. Additionally, acronyms used throughout the report are listed in Annex 2.

The units specified for the indicators in each of the methodology sheets represent, in most cases, recommended units based on data availability and should facilitate international analysis. Individual countries may decide to use different units based on national practices and the specific objectives sought in using this analytical tool. Annex 4 includes a summary of relevant units and conversions that may be useful to the reader.

It is recommended that all economic data (including gross domestic product, value added and prices) used to develop the EISD be in terms of constant prices (i.e. deflated to a base year — for example, 2000). These data may be in national currencies. In the case of international analysis, the monetary units should be converted into a common currency (e.g. US dollars or euros), preferably in terms of purchasing power parity or, for specific applications, in terms of exchange rates.

SOCIAL DIMENSION

SOC1: Share of households (or population) without electricity or commercial energy, or heavily dependent on non-commercial energy

Brief Definition	Share of households or population with no access to commercial energy services including electricity, or heavily dependent on 'traditional' non-commercial energy options, such as fuelwood, crop wastes and animal dung
Units	Percentage
Alternative Definitions	Per capita consumption of non-commercial or traditional energy
Agenda 21	Chapter 3: Combating poverty

POLICY RELEVANCE

(a) Purpose: To monitor progress in accessibility and affordability of commercial energy services including electricity.

(b) Relevance to Sustainable Development: Commercial energy services are crucial to providing adequate food, shelter, water, sanitation, medical care, education and access to communication. Lack of access to modern energy services contributes to poverty and deprivation, and limits economic development. Furthermore, adequate, affordable and reliable energy services are necessary to guarantee sustainable economic and human development.

It is estimated that 2 billion people, or about one-third of the world's population, depend mainly on traditional biomass sources of energy; 1.7 billion are without electricity. About 300 million people have been connected to electricity grids or have been provided with modern biomass or other forms of commercial energy options since 1993. However, in the absence of adequate measures, the number of people with no access to commercial energy will remain stable or continue to grow as demographic growth outpaces electrification in some parts of the world. Therefore, a sustainable development goal is to increase the accessibility and affordability of energy services for the lower-income groups of the population in developing countries so as to alleviate poverty and promote social and economic development.

(c) International Conventions and Agreements: None.

(d) International Targets/Recommended Standards: The Johannesburg Plan of Implementation (JPOI) of the World Summit on Sustainable Development held in 2002 includes the aim of improving access to reliable and affordable energy services.

(e) Linkages to Other Indicators: This indicator is linked to the use of non-commercial fuels, to energy prices and to several indicators of the social dimension, such as income inequality, share of household income spent on fuel and electricity, energy use relative to income level, urbanization, etc. The indicator might indirectly reflect a related use of forest resources as fuelwood, which in turn could cause deforestation.

METHODOLOGICAL DESCRIPTION

(a) Underlying Definitions and Concepts: Consumption of traditional fuels refers to the non-commercial consumption of fuelwood, charcoal, bagasse, and animal and vegetable wastes. Total household energy use might comprise commercial energy as well as traditional (non-commercial) fuels.

Households choose among energy options on the basis of fuel accessibility and affordability, the household's socioeconomic characteristics and attitudes, and the attributes of the different fuels. Lack of access to commercial energy implies unsatisfied energy requirements or the use of traditional fuels. If commercial energy services and electricity are available, income is the main characteristic that appears to influence a household's choice of fuel. Different income groups use different fuels, and the poor in many developing countries to a great extent meet their energy demand using traditional biomass fuels, either because of a lack of access to commercial energy services or because of limited income. National shares of traditional fuel in total energy use do not accurately reflect this indicator, as the average figures may strongly differ from corresponding figures for each income group of the population. Therefore, the preferred indicator is the percentage of households or population with no access to commercial energy options, or heavily dependent on 'traditional' non-commercial energy options, such as wood, crop wastes and animal dung.

(b) Measuring Methods: This indicator is defined by the share of households (or population) without access to commercial energy or electricity and by the share of households for which dependence on non-commercial (traditional) fuel exceeds 75% of total energy use.

(c) Limitations of the Indicators: Availability of data on the number of households or share of the population without access to commercial energy or electricity may be a limitation. Heavy dependence on non-commercial energy, defined as 75% dependence on traditional energy, is an arbitrary benchmark for this indicator.

(d) Alternative Definitions/Indicators: An alternative indicator that may be useful is 'Per capita consumption of non-commercial or traditional energy'. However, this does not really capture the essence of the issue.

ASSESSMENT OF DATA

(a) Data Needed to Compile the Indicator: The number of households or share of the population without access to electricity or to commercial energy and for which the share of non-commercial fuel consumption exceeds 75% of their energy use, and the total number of households in a specific country or a region.

(b) National and International Data Availability and Sources: The most important source of data on commercial and non-commercial fuel and electricity consumption is household surveys. The results of these surveys can be obtained from reports published by government statistical agencies. About two-thirds of the developing countries have conducted sample household surveys that are representative nationally, and some of these provide high-quality data on living standards. International agencies such as the United Nations Children's Fund (UNICEF) also carry out their own surveys of households.

Data on household fuel and electricity consumption by average population are available from the International Energy Agency (IEA) *Energy Balances of OECD Countries* and *Energy Balances of Non-OECD Countries*.

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<u>SOC2:</u> Share of household income spent on fuel and electricity

Brief Definition	Share of household disposable income (or private consumption) spent on fuel and electricity (on average and for the 20% of the population with the lowest income)
Units	Percentage
Alternative Definitions	Share of income needed to satisfy minimum household commercial energy requirements for household income group
Agenda 21	Chapter 3: Combating poverty

POLICY RELEVANCE

(a) Purpose: This indicator provides a measure of energy affordability for the average household and for the poorest segment of households.

(b) Relevance to Sustainable Development: From a sustainable development perspective, it is important to examine income, wealth and in particular affordability of modern energy services across the population. A country may have a high per capita gross domestic product (GDP), but its income distribution may be so skewed that a large percentage of the population has no possibility to meet their needs for commercial household energy at current energy prices and private income levels. Therefore, there is a need to decrease the burden of expenditure on fuel and electricity in household budgets for the lower-income groups of the population in developing countries, so as to promote social and economic development.

(c) International Conventions and Agreements: None.

(d) International Targets/ Recommended Standards: None.

(e) Linkages to Other Indicators: This indicator is linked to energy prices and to several indicators of the social dimension, such as income inequality, shares of households without access to electricity or heavily dependent on non-commercial energy services and energy use relative to income level.

METHODOLOGICAL DESCRIPTION

(a) Underlying Definitions and Concepts: This indicator corresponds to the overall household expenditures on commercial energy divided by total disposable income or private consumption. Expenditure on energy can be obtained from surveys of household expenditure or from the sum of all the consumed energy commodities multiplied by their corresponding unit price.

Per capita consumption by the overall population and by the 20% of the population with the lowest income may be assessed through the distribution of income. Each distribution is based on percentiles of population — rather than of households — with households ranked by income or expenditure per person.

(b) Measuring Methods: There are a number of choices about data that can influence the precise value of disposable income (private consumption) per capita. It is important how 'income' is measured — for example, whether it is total household income or per capita household income, or income per equivalent adult. In addition, it matters whether or not the incomes are weighted by household size, since households with lower incomes per person tend to be larger.

The World Bank, for example, prefers to weight by household size and calculate the shares held by persons rather than households for most purposes. As a general rule, the World Bank also considers household consumption expenditure to be a more reliable indicator of welfare than income. Incomes can vary excessively over time and are also more difficult to measure accurately, particularly in developing countries.

If data on energy expenditures are not available, the amount of energy consumed and corresponding fuel prices must be used. Because prices change through the year, the data collected must refer to a fixed date.

(c) Limitations of the Indicators: Availability of data on a number of developing countries may be a limitation.

(d) Alternative Definitions/Indicators: A more representative indicator of affordability is the share of income needed to satisfy minimum household commercial energy requirements according to household income group. The minimum energy requirements are multiplied by the corresponding energy fuel prices to determine the minimum energy requirement expenditures. The share is then calculated by dividing by the income corresponding to each income group. Countries would benefit from the development of this alternative indicator, although it is clear that data availability represents a major problem in most countries, especially developing countries. The indicator implies the definition of minimum energy requirements for representative households for each income group. Defining minimum energy requirements is a very subjective task and may prove to be difficult and controversial.

ASSESSMENT OF DATA

(a) Data Needed to Compile the Indicator: Annual household energy expenditure, or annual household fuel consumption multiplied by the corresponding energy fuel prices, and household disposable income or private consumption for the overall population and for the 20% of the population with the lowest income.

(b) National and International Data Availability and Sources: At the national level the most important source of data on disposable income (private consumption) and structure of consumption is household surveys. The results of these surveys can be obtained from reports published by national statistical agencies. About two-thirds of the developing countries have conducted sample household surveys that are representative nationally, and some of these provide high-quality data on living standards. These surveys are carried out on an irregular basis and may be targeted to specific income groups or geographic areas. Generally, data on the detailed structure of consumption in low- and middle-income economies are weak. In some countries, surveys are limited to urban areas or even to capital cities and so do not reflect national spending patterns. Urban surveys tend to show lower-than-average shares for food and higher-than-average shares for gross rent, fuel and power, transport and communications, and other consumption.

Data can also be obtained from international agencies such as the World Bank and from the United Nations Children's Fund (UNICEF), which carries out its own surveys of households. Household consumption structure, including the share of household income spent on fuel and power, was reported by the World Bank in the 2000 edition of the *World Development Indicators*. Data for developed countries can be obtained from Eurostat and the Organisation for Economic Co-operation and Development (OECD). Data from the European Community Household Panel are currently available for 1995 and 1996.

Data on household energy use are also available from the International Energy Agency (IEA). However, until the early 1980s, the household or residential sector was not well distinguished from the service/commercial sector in OECD energy statistics, particularly for liquid and solid fuels. In OECD countries, this distinction is now common. In developing countries, data often distinguish between residential and commercial consumption of electricity and natural gas, but users of liquid and solid fuels are often not accurately identified. Many national energy balances thus fail to distinguish between the residential and service/commercial sectors. Such problems are indicated when data show electricity and natural gas consumption for both the residential and service/commercial sectors, while liquid and solid fuel consumption is shown for only one of the two sectors.

Household fuel and electricity prices in developed countries are generally available, both nationally and internationally (OECD, Eurostat), but the availability of price data varies from one country to another. For developing countries, data may be available from national sources.

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SOC3: Household energy use for each income group and corresponding fuel mix

Brief Definition	Energy use of representative households for each income group and the corresponding fuel mix Household incomes divided into quintiles (20%)
Units	Energy: tonnes of oil equivalent (toe) per year per household Electricity: kilowatt-hours (kWh) per year and per household. Percentage for fuel mix
Alternative Definitions	None
Agenda 21	Chapter 3: Combating poverty

POLICY RELEVANCE

(a) Purpose: This indicator provides a measure of energy disparity and affordability. The indicator is an assessment of the amount of electricity and fuels used by the population relative to income level and the corresponding fuel mix.

(b) Relevance to Sustainable Development: From a sustainable development perspective, it is important to examine income, wealth and in particular affordability of modern energy services across the population. A country may have a high per capita gross domestic product (GDP), but its income distribution may be so skewed that a large percentage of the population has no possibility to meet their needs for commercial household energy at current energy prices and private income levels. This is particularly relevant to developing countries, where one-third of the population does not have access to commercial energy. Therefore, there is a need to increase energy availability and affordability for the lower-income groups of the population in many developing countries so as to promote social and economic development.

(c) International Conventions and Agreements: None.

(d) International Targets/ Recommended Standards: None.

(e) Linkages to Other Indicators: This indicator is linked to energy prices and to several indicators of the social dimension, such as shares of households without access to electricity or heavily dependent on non-commercial energy options, shares of income spent on fuel and electricity, etc. The indicator might indirectly reflect a related use of forest resources as fuelwood, which in turn could cause deforestation.

METHODOLOGICAL DESCRIPTION

(a) Underlying Definitions and Concepts: This indicator provides information about different levels of energy use and changes in fuel mix in relation to income level. Energy use per household represents final energy use including traditional or non-commercial fuel. If data are available only on household energy fuel expenditures, then the corresponding fuel prices are necessary to compute the amount of energy used. Household income, by income group in quintiles, corresponds to the distribution of income available for most countries. Each distribution is based on percentiles of population — rather than on households — with households ranked by income or expenditure per person. The values of the disposable income per capita and consumer prices by commodity should be in national currencies.

(b) Measuring Methods: This indicator reflects energy use by fuel mix (in energy units) relative to income level. If energy prices are needed, price data must refer to a fixed date. Overall energy use can be computed by converting fuel energy use to a single energy unit (e.g. toe). Also, energy use can be presented by fuel type using different energy units (e.g. heating and cooking fuel in toe and electricity in kWh).

(c) Limitations of the Indicators: Availability of data for a number of developing countries may be a limitation.

(d) Alternative Definitions/Indicators: None.

ASSESSMENT OF DATA

(a) Data Needed to Compile the Indicator: Energy use according to household income group per fuel type. If data are available only on household energy fuel expenditures, then the corresponding fuel prices are necessary.

(b) National and International Data Availability and Sources: The most important source of data on disposable income is household surveys. The results of these surveys can be obtained from government statistical agencies, often via published reports. About two-thirds of the developing countries have done sample household surveys that are representative nationally, and some of these provide high-quality data on living standards.

Data can also be obtained from international agencies such as the World Bank. The United Nations Children's Fund (UNICEF) also carries out its own surveys of households. Data for developed countries can be obtained from Eurostat and the

Organisation for Economic Co-operation and Development (OECD). Data from the European Community Household Panel are currently available for 1995 and 1996.

Data on energy prices are available from national sources and are compiled by the International Energy Agency (IEA) for OECD and non-OECD countries.

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<u>SOC4:</u> Accident fatalities per energy produced by fuel chain

Brief Definition	Number of annual fatalities per energy produced by fuel chain
Units	Number of fatalities by fuel chains per energy or electricity produced annually
Alternative Definitions	Total number of accident fatalities
Agenda 21	Chapter 6: Protecting and promoting human health

POLICY RELEVANCE

(a) Purpose: This indicator shows the number of fatalities per energy produced in energy systems and related activities. The indicator is used to assess the risk to human health derived from energy systems, and in particular by various fuel chains per energy produced.

(b) Relevance to Sustainable Development: Energy systems are associated with a vast array of insults and impacts including environmental health risks. Exploring the sustainability of current energy supply practices indicates that the extraction, transport, use and waste management of energy options involve important health hazards that in many cases result in fatalities. Although this issue is often ignored, the risks to the population and the rates of occupational injury and mortality from energy-related accidents are high. Operating a liquefied natural gas terminal, transporting petroleum, running a coal mine or exploiting a hydropower dam also require the conscious assessment of system-wide resilience in response to human or technical failure in order to minimize the risk of accidents and consequently of fatalities. Nuclear energy represents a special case in this context in that the scope of an accident could be potentially large, but major efforts exist to actively assess and manage the multidimensional risk in the nuclear industry. Also, the use of traditional fuels in many countries is linked to fatalities resulting from fires and smoke inhalation.

(c) International Conventions and Agreements: None.

(d) International Targets/Recommended Standards: None.

(e) Linkages to Other Indicators: This indicator is closely linked to some indicators of the economic dimension, such as the level of energy use and production, fuel mix, etc. Also, the indicator is linked to other social indicators such as share of households without electricity or heavily dependent on non-commercial energy.

METHODOLOGICAL DESCRIPTION

(a) Underlying Definitions and Concepts: To compute the indicator, identification of energy-related accidents and their allocation to specific fuel cycles and subsequently to energy produced are required. For practical reasons, there is a discrepancy between the number of accidents that actually occur and those that are published and analysed in reports or periodicals. Therefore, the relatively rare major accidents have a much greater probability of being registered than do the much more frequent or routine accidents that are less publicized.

(b) Measuring Methods: Types of accidents for various fuel chains that may result in fatalities include the following:

Coal: Explosions or fires in underground coal mines; collapse of roof or walls in underground or surface mines; tailing dam collapse; haulage/vehicular accidents.

Oil: Offshore rig accidents; fires or explosions from leaks or process plant failures; well blowouts causing leaks; transportation accidents resulting in fires, explosions or major spills; loss of content in storage farms resulting in fires or explosions.

Natural Gas (includes liquefied petroleum gas): Same as for oil, except for spills.

Nuclear: Loss of coolant or reactivity transient and reactor meltdown; accidents during shipment of high-level radioactive waste.

Hydro: Rupture or overtopping of dam.

Power Sector: Explosions or fires; failures of equipment for electricity generation, transportation or distribution.

(c) Limitations of the Indicators: Fatalities alone do not cover all types of consequences of accidents. In spite of the importance of monitoring all consequences, the lack of corresponding information does not allow this issue to be fully addressed. It is recognized that the current state of knowledge concerning delayed health effects from accidents associated with different energy systems is limited.

(d) Alternative Definitions/Indicators: Total number of accident fatalities.

ASSESSMENT OF DATA

(a) Data Needed to Compile the Indicator: Annual number of fatalities from the various energy chains and from various types of power generation per energy produced.

(b) National and International Data Availability: Numerous sources of information at the national and international levels exist, but their availability, completeness, scope, development status and quality vary enormously. The available data normally cover human-induced accidents in a variety of sectors and in some cases also natural disasters, but very few databases deal explicitly with energy-related accidents. The Major Accident Reporting System (MARS) was set up by the European Commission (EC) and is operated by the Major Accident Hazards Bureau (MAHB) at the EC's Joint Research Centre in Ispra, Italy. The Worldwide Offshore Accident Databank (WOAD) was established by the Norwegian organization Det Norske Veritas.

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ECONOMIC DIMENSION

<u>ECO1:</u> Energy use per capita

Brief Definition	Energy use in terms of total primary energy supply (TPES), total final consumption (TFC) and final electricity use per capita
Units	Energy: tonnes of oil equivalent (toe) per capita Electricity: kilowatt-hours (kWh) per capita
Alternative Definitions	None
Agenda 21	Chapter 4: Consumption and production patterns

POLICY RELEVANCE

(a) Purpose: This indicator measures the level of energy use on a per capita basis and reflects the energy-use patterns and aggregate energy intensity of a society.

(b) Relevance to Sustainable Development: Energy is a key factor in economic development and in providing vital services that improve quality of life. Although energy is a key requirement for economic progress, its production, use and by-products have resulted in major pressures on the environment, both by depleting resources and by creating pollution. On the one hand, the long-term aim is for development and prosperity to continue through gains in energy efficiency, rather than increased use, and through a transition towards the use of environmentally friendly energy options. On the other hand, limited access to energy is a serious constraint in the developing world, where the per capita use of energy is less than one-sixth that of the industrialized world.

(c) International Conventions and Agreements: Currently, there are no conventions or agreements that specifically refer to the regulation and/or limitation of energy use per capita. However, calls have been made for the prudent and rational utilization of natural resources (Article 174 of the Treaty Establishing the European Community — Nice, 2001), improved energy efficiency (The Energy Charter Protocol on Energy Efficiency and Related Environmental Aspects — Lisbon, 1994) and a switch to cleaner forms of energy. The United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol call for limitations on total greenhouse gas (GHG) emissions, which result mainly from the combustion of fossil fuels.

(d) International Targets/Recommended Standards: None.

(e) Linkages to Other Indicators: This indicator is closely linked with other economic indicators, such as energy use per unit of gross domestic product (GDP), energy prices, energy intensities and energy net imports; with environmental indicators such as GHG emissions, air quality and waste generation; and with social indicators such as household energy use for each income group.

METHODOLOGICAL DESCRIPTION

(a) Underlying Definitions and Concepts: Total primary energy supply (TPES) and total final consumption (TFC) are key aggregates in the energy balances.

TPES comprises production of primary energy — for example, coal, crude oil, natural gas, nuclear, hydro and other non-combustible and combustible renewables — plus imports, less exports of all energy carriers, less international marine bunkers and finally corrected for net changes in energy stocks. Production refers to the first stage of production. International trade of energy commodities is based on the general trade system; that is, all goods entering and leaving the national boundaries of a country are recorded as imports and exports, respectively. In general, data on stocks refer to changes in stocks of producers, importers and/or industrial consumers at the beginning and the end of the year.

TFC refers to the sum of consumption by the different end-use sectors and thus excludes energy consumed, or losses incurred, in the conversion, transformation and distribution of the various energy carriers.

(b) Measuring Methods: This indicator is calculated as the ratio of the total annual use of energy to the mid-year population. The following entries are to be specified for the numerator of the indicator: total primary energy supply, total final consumption and total final electricity consumption.

(c) Limitations of the Indicator: The actual value of the indicator is strongly influenced by a multitude of economic, social and geographical factors.

(d) Alternative Definitions/Indicators: None.

ASSESSMENT OF DATA

(a) Data Needed to Compile the Indicator: Energy commodity data for production and use (energy balances) and mid-year population estimates.

(b) National and International Data Availability: Energy commodity data for production and use, and population data are regularly available for most countries at the national level and for some countries at the sub-national level. Both types of data are compiled by and available from national statistical offices and country publications.

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<u>ECO2:</u> Energy use per unit of GDP

Brief Definition	Ratio of total primary energy supply (TPES), total final consumption (TFC) and electricity use to gross domestic product (GDP)
Units	Energy: tonnes of oil equivalent (toe) per US dollar Electricity: kilowatt-hours (kWh) per US dollar
Alternative Definitions	Sectoral energy intensities
Agenda 21	Chapter 4: Consumption and production patterns

POLICY RELEVANCE

(a) Purpose: This indicator reflects the trends in overall energy use relative to GDP, indicating the general relationship of energy use to economic development.

(b) Relevance to Sustainable Development: Energy is essential for economic and social development. However, energy use affects resource availability and the environment. In particular, fossil fuel use is a major cause of air pollution and climate change. Improving energy efficiency and decoupling economic development from energy use are important sustainable development objectives.

(c) International Conventions and Agreements: Currently, there are no conventions or agreements that specifically refer to the regulation and/or limitation of energy use per unit of GDP. However, Agenda 21 calls for considering how economies can grow and prosper while reducing their use of energy and materials. Also, it encourages the reduction of the amount of energy and materials used per unit of goods/services produced. The Johannesburg Plan of Implementation that was agreed at the 2002 World Summit on Sustainable Development also calls for enhanced energy efficiency and greater use of advanced energy technologies. At the regional level, calls have been made for the prudent and rational utilization of natural resources (Article 174 of the Treaty Establishing the European Community — Nice, 2001), improved energy efficiency (The Energy Charter Protocol on Energy Efficiency and Related Environmental Aspects — Lisbon, 1994) and a switch to cleaner forms of energy.

(d) International Targets/Recommended Standards: There is no specific target for energy intensity.

(e) Linkages to Other Indicators: The ratio of energy use to GDP is an aggregate energy intensity indicator and thus is linked to indicators of the energy intensities of the manufacturing, transport, service/commercial and residential sectors. This indicator is also linked to indicators for total energy use, greenhouse gas emissions and air pollution emissions.

METHODOLOGICAL DESCRIPTION

(a) Underlying Definitions and Concepts: The ratio of energy use to GDP is also called 'aggregate energy intensity' or 'economy-wide energy intensity'. The ratio of energy use to GDP indicates the total energy being used to support economic and social activity. It represents an aggregate of energy use resulting from a wide range of production and consumption activities. In specific economic sectors and sub-sectors, the ratio of energy use to output or activity is the 'energy intensity' (if the output is measured in economic units) or the 'specific energy requirement' (if the output is measured in physical units such as tonnes or passenger-kilometres [km]).

Due to the limitations described below, disaggregated energy intensities by sector (industrial, transport, residential, service/commercial, agricultural, construction, etc.) or sub-sector should be developed in addition to the energy per GDP intensity. For each sector or sub-sector, energy use can be related to a convenient measure of output to provide sectoral or sub-sectoral energy intensity. Examples include energy use for steel making relative to tonnes of steel produced; energy use by passenger vehicles relative to passenger-km or vehicle-km; and energy use in buildings relative to their floor area. (See separate methodology sheets for intensities of the industrial, transport, service/commercial, agriculture and household sectors.)

(b) Measuring Methods: This indicator is calculated as the ratio of energy use to economic output.

Energy Use: TPES, TFC and final electricity consumption are obtained from national energy balances and international statistical sources. TPES and TFC are measured in toe; electricity use is measured in kWh.

Output: GDP could be measured in US dollars, converted from the real national currency at purchasing power parity (PPP) for the base year to which the national currency was deflated.

(c) Limitations of the Indicator: The ratio of aggregate energy use to GDP is not an ideal indicator of energy efficiency, sustainability of energy use or technological development, as it has been commonly used. The aggregate ratio depends on the energy intensities of sectors or activities, but also on factors such as climate, geography and the structure of the economy. Consequently, changes in the ratio over time are influenced by factors that are not related to changes in energy efficiency (such as changes in economic structure). It is thus important to supplement the energy use per GDP indicator with energy intensities disaggregated by sector, since these disaggregated indicators are a better representation of energy efficiency developments.

Comparisons among countries of the ratio of energy use to GDP are complicated by geographical factors. Large countries, for example, tend to have high levels of freight transportation, as many goods are distributed nationwide. Compared with countries with moderate climates, cold countries might consume considerably more energy per capita due to demand for space heating. Countries with hot climates might use more energy per capita as a result of demand for air conditioning. Countries with economies that depend mainly on raw-material industries might use larger quantities of energy per unit of manufacturing output compared with countries that import processed materials owing to the high energy intensity of raw-material processing. Canada, for example, has a high ratio of energy use to GDP, resulting in part from the fact that it is a large country with relatively cold weather and an economy that depends on a large raw-material processing sector. In Japan, the climate is milder, raw materials are limited, and the high population density results in smaller residential units and less distance travelled, contributing to a lower ratio of energy use to GDP.

Interpreting the ratio of energy use to GDP in terms of environmental impact or sustainability is also complicated by differences in environmental impacts among energy options. Canada, for example, has substantial hydropower, nuclear power and natural gas, which are energy sources that have lower environmental impacts than coal or oil with respect to air pollution and climate change.

Given the large number of factors that affect energy use, the ratio of total energy use to GDP should not be used alone as an indicator of energy efficiency or sustainability for policy-making purposes.

(d) Alternative Definitions/Indicators: The ratio of sectoral or sub-sectoral energy use to the output or activity of the sector or sub-sector provides a detailed indication of energy intensity.

ASSESSMENT OF DATA

(a) Data Needed to Compile the Indicator: Energy use in terms of TPES, TFC and electricity use, and real GDP in US dollars or national currency at PPP for corresponding years and for a base year.

(b) National and International Data Availability and Sources: The International Energy Agency (IEA) and Eurostat maintain the most comprehensive sets of energy balances and energy accounts, based primarily on national data or data collected from reliable regional agencies and statistical offices. GDP data are primarily available in national accounts.

GDP and value added by industry are published by international organizations. The *International Financial Statistics* of the International Monetary Fund provide nominal and real GDP for most countries. Data on components of GDP are often available from regional development banks or national sources.

Regional data are available from regional organizations such as the Asia Pacific Energy Research Centre (APERC) and the Organización Latinoamericana de Energía (OLADE).

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<u>ECO3:</u> Efficiency of energy conversion and distribution

Brief Definition	Efficiency of energy conversion and distribution, including fossil fuel efficiency for electricity generation, efficiency of oil refining and losses occurring during electricity transmission and distribution, and gas transportation and distribution
Units	Percentage
Alternative Definitions	None
Agenda 21	Chapter 4: Consumption and production patterns

POLICY RELEVANCE

(a) Purpose: This indicator measures the efficiency of energy conversion and distribution systems in various energy supply chains including losses occurring during electricity transmission and distribution, and gas transportation and distribution.

(b) Relevance to Sustainable Development: Improving energy supply efficiency and reducing losses during energy conversion and transportation processes are important sustainable development objectives for countries all over the world. Improvements in the efficiency of energy supply systems translate into more effective utilization of energy resources and into reductions of negative environmental impacts.

(c) International Conventions and Agreements: Currently, there are no international conventions or agreements that specifically refer to regulation or improvements in energy supply efficiency. However, Agenda 21 calls for encouraging greater efficiency in the use of energy, in particular on the supply side, and this call was renewed by the World Summit on Sustainable Development in Johannesburg. Also, Agenda 21 calls for considering how economies can grow and prosper while reducing the losses from various fuel-cycle chains.

(d) International Targets/Recommended Standards: There is no specific target for energy efficiency.

(e) Linkages to Other Indicators: This indicator is closely linked with other indicators of the economic and environmental dimensions, including energy use, energy intensities, energy mix, greenhouse gas and air pollutant emissions, and soil and water contamination.

METHODOLOGICAL DESCRIPTION

(a) Underlying Definitions and Concepts: This indicator comprises the following:

Fossil fuel efficiency for electricity generation, defined as gross production of electricity (including own use of electricity by power plants) from fossil fuel power plants relative to fossil fuel inputs. Significant improvements in the average efficiency of thermal power plants result from fuel switching; the commissioning of new, high-efficiency generating plants; and the decommissioning of older, inefficient plants. In particular, a move from coal towards gas, a fuel used in high-efficiency combined gas-steam cycle, usually incurs higher efficiency gains. The indicator can be developed separately for oil-, gas- and coal-based generation to isolate the fuel-switching effect.

Electricity transmission and distribution efficiency, defined as the ratio of final electricity consumption to electricity supply. Electric power transmission and distribution losses include losses during transmission between sources of supply and points of distribution and during the distribution to consumers, including pilferage.

Gas distribution efficiency, defined as the ratio of final gas consumption to gas supply. Gas supply is defined as primary gas supply less gas input to power stations. Gas transportation and distribution losses include losses during transportation between sources of supply and points of distribution, including own-use gas consumed by gas pumping systems, and during the distribution to consumers.

Oil refining efficiency, defined as the average percentage of refinery output products to refinery input, including feedstock. Both factors are expressed in energy units.

(b) Measuring Methods: The amount of energy produced, supplied and used can be derived from the energy statistics and balances published by individual countries or various international or regional organizations. The amounts of all primary energy options, such as fossil fuel, electricity and heat, need to be considered.

(c) Limitations of the Indicator: Data on the efficiency of energy conversion and distribution are not readily available for some countries.

(d) Alternative Definitions/Indicators: None.

ASSESSMENT OF DATA

(a) Data Needed to Compile the Indicator: Energy commodity data for production and use (energy balances); output and input of refineries; gas consumption and supplies; and structure of electricity supplies.

(b) National and International Data Availability: Energy commodity data for production and consumption (energy balances) are regularly available for most countries at the national level, and for some countries at the sub-national level. Both types of data are compiled by and available from national statistical offices and country publications.

Internationally, the International Energy Agency (IEA) and Eurostat maintain the most thorough sets of energy balances and energy accounts, based primarily on national data or data collected from reliable regional agencies. Other sources of data include the World Bank, the United Nations, the International Atomic Energy Agency (IAEA), the European Environment Agency (EEA), etc.

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<u>ECO4:</u> **Reserves-to-production ratio**

Brief Definition	Ratio of energy reserves remaining at the end of a year to the production of energy in that year. Also, lifetime of proven energy reserves or the production life index
Units	years
Alternative Definitions	Total reserves Depletion rate of reserves
Agenda 21	Chapter 4: Consumption and production patterns

POLICY RELEVANCE

(a) Purpose: The purpose of this indicator is to measure the availability of national energy reserves with respect to corresponding fuel production. Reserves are generally defined as identified (demonstrated and inferred) resources that are economically recoverable at the time of assessment. Reserves are also defined as those quantities that geologic and engineering information indicates can be recovered with reasonable certainty in the future from known or identified energy resources under existing economic and technical conditions The indicator considers fuels such as oil, natural gas, coal and uranium, and provides a relative measure of the length of time that proven reserves would last if production were to continue at current levels.

(b) Relevance to Sustainable Development: Availability of energy fuel supplies is a key aspect of sustainability. This indicator provides a basis for estimating future energy supplies with respect to current availability of energy reserves and levels of production. The proper management of proven energy reserves is a necessary component of national sustainable energy programmes.

(c) International Conventions and Agreements: None.

(d) International Targets/Recommended Standards: None.

(e) Linkages to Other Indicators: This indicator is linked to indicators of annual energy production, annual energy use, imports, prices and resources.

METHODOLOGICAL DESCRIPTION

(a) Underlying Definitions and Concepts: Proven reserves indicate the resources in place that have been assessed as exploitable under present and expected economic conditions with available technology.

(b) Measuring Methods: The estimates are based on the results of geological and exploratory information about an area or on evidence of the duplication or parallelism of geological conditions that occurs in known deposits. Unproven deposits are not included. The lifetime of proven fuel reserves in terms of the reserves-to-production ratio is computed by dividing the proven energy reserves of a commodity at the end of a year by the total production of that commodity in that year.

(c) Limitations of the Indicator: The rate of use of energy reserves depends on many factors, including economic conditions, prices, technological progress and exploration efforts. Therefore, this indicator represents only a relative measure of reserve availability. For many countries, reserve-to-production ratios for oil and gas have been constant over many years, despite increasing exploitation of these resources. This is because when known reserves start to be depleted, greater effort typically is put into identifying new reserves as a replacement. Trends in reserve-to-production ratios may therefore underestimate the total resource available, on the one hand, while providing inaccurate information about the extent to which a finite resource is being exhausted, on the other hand.

(d) Alternative Definitions/Indicators: The total reserves and depletion rate are alternative measures for this indicator.

ASSESSMENT OF DATA

(a) Data Needed to Compile the Indicator: Data on available energy reserves and production.

(b) National and International Data Availability: Data on proven fossil fuel reserves are available from the annual publication *Survey of Energy Resources* by the World Energy Council and are subject to frequent revision. Such data are also available from national and international oil and gas companies. Data on uranium reserves are available from joint publications of the International Atomic Energy Agency (IAEA) and the Nuclear Energy Agency (NEA).

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ECO5: Resources-to-production ratio

Brief Definition	Ratio of the energy resources remaining at the end of a year to the production of energy in that year Also, lifetime of proven energy resources
Units	years
Alternative Definitions	Total resources Depletion rate of resources
Agenda 21	Chapter 4: Consumption and production patterns

POLICY RELEVANCE

(a) Purpose: The purpose of this indicator is to measure the availability of national energy resources with respect to corresponding fuel production. Resources are generally defined as concentrations of naturally occurring solid, liquid or gaseous material in or on the Earth's crust in a form that makes economic extraction potentially feasible. Total resources include reserves, and hypothetical and speculative undiscovered resources. This indicator considers fuels such as oil, natural gas, coal and uranium. It provides a relative measure of the length of time that resources would last if production were to continue at current levels.

(b) Relevance to Sustainable Development: The availability and security of energy fuel supplies are key aspects of sustainability. This indicator provides a basis for assessing possible future energy supplies with respect to the current availability of energy resources and levels of production. The proper management of energy resources is a necessary component of national sustainable energy programmes.

(c) International Conventions and Agreements: None.

(d) International Targets/Recommended Standards: None.

(e) Linkages to Other Indicators: This indicator is linked to indicators of annual energy production, annual energy use, imports, prices and reserves.

METHODOLOGICAL DESCRIPTION

(a) Underlying Definitions and Concepts: Resources include reserves, estimated additional resources and speculative resources. Proven reserves indicate the resources in place that have been assessed as exploitable under present and expected economic conditions with available technology. Estimated additional resources are resources inferred to exist. Speculative resources are resources thought to exist, mostly on the basis of indirect evidence and geological extrapolations.

(b) Measuring Methods: The lifetime of fuel resources in terms of the resources-to-production ratio is computed by dividing the total energy resources of a commodity at the end of a year by the total production of that commodity in that year.

(c) Limitations of the Indicator: The rate of use of energy resources depends on many factors, including economic conditions, prices, technological progress and exploration efforts. Therefore, this indicator represents only a relative measure of resource availability.

(d) Alternative Definitions/Indicators: The total resources and depletion rate are alternative definitions for this indicator.

ASSESSMENT OF DATA

(a) Data Needed to Compile the Indicator: Data on available energy resources and production.

(b) National and International Data Availability: Data on fossil fuel resources are available from the annual publication *Survey of Energy Resources* by the World Energy Council and are subject to frequent revision. Data on uranium resources are available from joint publications of the International Atomic Energy Agency (IAEA) and the Nuclear Energy Agency (NEA). Data are also available from national and international oil and gas companies.

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- WEC, various editions. *Survey of Energy Resources*. Published annually. London, UK: World Energy Council.

ECO6: Industrial energy intensities

Brief Definition	Energy use per unit of value added in the industrial sector and by selected energy-intensive industries
Units	Energy: tonnes of oil equivalent (toe) per US dollar Electricity: kilowatt-hours (kWh) per US dollar
Alternative Definition	Energy use per unit of physical output in the industrial sector, manufacturing branches and selected energy-intensive industries
Agenda 21	Chapter 4: Consumption and production patterns

POLICY RELEVANCE

(a) Purpose: The industrial sector is a major user of energy. This set of indicators measures the aggregate energy use of the industrial sector and selected energy-intensive industries per corresponding value added. Intensities provide information about the relative energy use per unit of output. The set is used to analyse trends in energy efficiency and in changes in product composition and fuel mix as they affect industrial, branch and product intensities. In addition, this set of indicators can be used for evaluating trends in technological improvements and changes in the structure of the industrial sector and sub-sectors.

(b) Relevance to Sustainable Development: Improving energy efficiency and reducing energy intensities in industrial processes are important sustainable development objectives for countries all over the world. Improvements in intensities translate into more effective utilization of energy resources and into reductions of negative environmental impacts.

(c) International Conventions and Agreements: There are no specific international conventions or agreements directly related to the reduction of energy intensities. However, international conventions on the reduction of emissions, such as the United Nations Framework Convention on Climate Change and its Kyoto Protocol, might influence intensity levels. The importance of energy efficiency and the rational use of energy has also been highlighted by Agenda 21, at the World Summit on Sustainable Development in Johannesburg and by various European Union treaties.

(d) International Targets/Recommended Standards: Although there are no specific international targets regarding energy intensities or energy efficiency, many industrialized countries have targets for reducing energy use and carbon emissions and other pollutants from industrial and manufacturing branches.

(e) Linkages to Other Indicators: This indicator is part of a set of energy intensity indicators in different sectors (transport, agriculture, service/commercial and residential), all linked to the aggregate energy use per unit of gross domestic product (GDP) indicator. These indicators are also linked to indicators of final and primary energy use, electricity use, greenhouse gas emissions, air pollutant emissions and depletion of energy resources.

METHODOLOGICAL DESCRIPTION

(a) Underlying Definitions and Concepts: Energy use per unit of value added is one way of measuring energy requirements relative to manufacturing production.

While energy use per unit of physical output is a better indicator of energy efficiency in specific manufacturing processes, energy use per unit of economic output is more useful both for relating energy efficiency to economic activity and for aggregating and comparing energy efficiency across manufacturing sectors or across the entire economy.

Energy-intensive industries that may be considered include iron and steel, non-ferrous metals, chemicals, petroleum refining, non-metallic minerals, cement, and paper and pulp.

Changes in intensities are affected by factors other than energy efficiency; therefore, analysing intensity trends provides important insights into how energy efficiency and other factors affect energy use. Annex 3 includes a decomposition method for energy intensities.

(b) Measuring Methods:

Energy Use: Energy use is usually measured as final energy at the point of consumption; that is, the factory or establishment. 'Own energy' (including internal use of hydropower, biofuels or internal waste heat) should be combined with purchased energy to obtain total final energy use.

Complications in interpreting energy-intensity data arise from the fact that some branches of manufacturing might be concentrated in regions of a country rich in certain kinds of power or heat sources, so that those branches constitute a lower energy burden on the economy than the indicator would suggest. Interpretation is also complicated when a particular branch has significant internal energy resources, such as captive hydropower, biofuels or coal.

For combined production of heat and electricity, no simple method exists for dividing the total energy used between these two outputs. Where excess heat or electricity is sold or provided to outside establishments or a grid, the energy required for this outgoing supply should not be allocated to the product of the establishment or branch.

In some cases, it might be preferable to measure total primary energy use including losses incurred in the external production and distribution of the purchased electricity and heat as these losses would occur if the establishment or branch used the primary energy directly. Primary energy use per unit of output measures the total energy burden on the economy of a unit of output from a given industry. Generally, the energy loss from converting primary energy to electricity is estimated using the average ratio for electricity production in the economy. There are various conventions for calculating the primary energy corresponding to electricity produced by nuclear, hydropower or geothermal sources.

It is also possible to measure total energy use, internal and external for any final product, by using input-output tables. This approach allows the measuring of the energy embodied in materials and intermediate products; however, this is a very data-intensive task and input-output tables are not produced regularly.

Units: toe for final energy and kWh for electricity.

Output: Both value added and gross output may be used to measure economic output from the industrial sector. In both cases, the real national currency is used, deflated by the deflator for the sector or branch to a base year. This step is crucial, so that the weight of each sector or branch reflects the correct weight in the base year. The value of output can then be converted to a common international currency, usually US dollars, using purchasing power parities (PPP). One alternative is to calculate the total value of production or shipments, or gross output. This represents the total value of all outputs from a given industry. Value added is equal to the contribution to GDP arising from the sector, which represents only the increase in economic output produced by the sector or branch in question.

The gross output measure tends to be more stable over time but has the disadvantage that it cannot be aggregated to total output because of double counting; the inputs to one branch may be the outputs of another branch. On the one hand, value added could be aggregated but may have greater fluctuations from year to year if input costs or output prices change. On the other hand, using value added allows the estimation of impacts on energy use from structural changes.

Unit: Constant currency. The market value of output in the real national currency is deflated to a base year using GDP deflators. The national currency can be converted to US dollars, using the PPP for the base year.

(c) Limitations of the Indicator: The aggregate indicator for the industrial sector reflects both the energy intensity of various branches of manufacturing and the composition of the manufacturing sector. Changes in the aggregate indicator can therefore be due either to changes in energy intensity or to changes in relative branch output (structure). Similarly, differences between countries may be due either to differences in energy efficiency or to differences in the structure of the manufacturing sector. A country with large energy-intensive industries, such as pulping, primary metals or fertilizers, for example, will have a high energy intensity, even if the industry is energy efficient. For this reason, it is desirable to disaggregate energy intensity by manufacturing branch and by industry.

Intensities measured as energy per value added at a disaggregated level are affected by changes in the structure within each branch — for example, by changes in the mix of metals produced within the non-ferrous metals sector or in the share of pulp versus paper in total paper and pulp value added. While desirable, detailed calculations, such as total energy use for particular products using input-output tables, are very data intensive and difficult to update regularly.

(d) Alternative Definitions/Indicators: Energy use per unit of physical output in industries. For some purposes, physical output would be preferable, but this is not possible using the energy-use statistics available in many countries, and there are many sectors for which aggregate physical output cannot be easily defined.

ASSESSMENT OF DATA

(a) Data Needed to Compile the Indicator: Energy and electricity use by industrial sector, by manufacturing branch and by selected industries; value added or gross output.

(b) National and International Data Availability and Sources: The United Nations compiles value added at the two- or three-digit level of the International Standard Industrial Classification (ISIC) system for developed and developing countries. The Organisation for Economic Co-operation and Development (OECD), as part of its STAN database, compiles value added in manufacturing at the three- and four-digit ISIC level for most OECD countries. The European Union produces data on value added at the two- and three-digit level in the NACE system, and suitable bridges exist to translate NACE into ISIC.

One persistent data problem at the aggregate level is distinguishing between 'industry' (ISIC, Divisions C, D, F and E) and 'manufacturing' (ISIC, Division D). Some countries also lump agriculture, forestry and fishing (ISIC, Divisions A and B) into the aggregate 'industrial sector' classification. For these reasons, it is strongly recommended that data be checked to ascertain exactly what sectors are covered.

Data on final energy use are compiled by the International Energy Agency (IEA) in the energy balances for OECD and non-OECD countries, but these data are given by main sector and not by main product. Thus it is difficult to track energy use related to the physical production of a certain product — for example, cement. Very few countries report data at this disaggregated level.

Regional data are available from regional organizations such as the Asia Pacific Energy Research Centre (APERC) and the Organización Latinoamericana de Energía (OLADE).

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ECO7: Agricultural energy intensities

Brief Definition	Final energy use per unit of agricultural value added
Units	Energy: tonnes of oil equivalent (toe) per US dollar Electricity: kilowatt-hours (kWh) per US dollar
Alternative Definition	Energy use per unit of agricultural output
Agenda 21	Chapter 4: Consumption and production patterns

POLICY RELEVANCE

(a) Purpose: This indicator is a measure of aggregate energy intensity in the agricultural sector that can be used for analysing trends, particularly in renewables and non-commercial energy use.

(b) Relevance to Sustainable Development: Energy is essential for most human activities, including agriculture. The availability of energy is a key factor for increasing agricultural productivity and for improving rural livelihoods. This indicator can be used to guide policy and investment decisions regarding energy requirements in all stages of agricultural production and energy efficiency. Renewable energy options such as solar, wind and bioenergy can contribute greatly to increased labour efficiency and diversified economic activities in rural areas.

It is worth noting that the specific functions of agriculture as an energy producer and agroecosystem regenerator are important components of sustainable development programmes in some countries.

(c) International Conventions and Agreements: No international agreements exist. Agenda 21 makes reference to the need to promote energy efficiency in all sectors.

(d) International Targets/Recommended Standards: No international targets exist or apply. Targets could be developed at the national level, depending on the country's range of agricultural products.

(e) Linkages to Other Indicators: This indicator is part of a set of energy intensity indicators in different sectors (manufacturing, transport, service/commercial and residential), with energy use per unit of gross domestic product (GDP) as an aggregate energy intensity indicator. It is also linked to indicators such as total energy, non-commercial energy and electricity use, greenhouse gas emissions and air pollutant emissions.

METHODOLOGICAL DESCRIPTION

(a) Underlying Definitions and Concepts: Energy use per unit of value added is one way of measuring energy requirements per unit of output in the agricultural sector. While energy use per unit of physical output is a better indicator of energy efficiency in specific agricultural processes, data supporting this level of disaggregation are rarely available. Measuring intensity in terms of economic output is useful for aggregating and comparing energy developments across the entire economy. Total energy use in agriculture derives from the energy inputs at all the stages of agricultural production and processing. The agricultural activities include land preparation, mechanization, fertilization, irrigation, harvesting, transport, processing and storage. Each of these stages uses different forms of energy (mechanical, electrical, thermal), which can be aggregated in equivalent units.

Changes in intensities are affected by factors other than energy efficiency; therefore, analysing intensity trends provides important insights into how energy efficiency and other factors affect energy use. Annex 3 includes a decomposition method for energy intensities.

(b) Measuring Methods:

Energy Use: Annual energy inputs for each stage of agricultural production and processing are determined and converted into equivalent units and aggregated as total energy. Energy use is usually measured at the point of consumption (i.e. the farm), and 'own energy' (including internal use, biomass, etc.) should be added to the purchased energy.

Units: toe for final energy and kWh for electricity.

Output: Net economic output is measured in agricultural value added (International Standard Industrial Classification [ISIC], Division A). The sector comprises crops and livestock production, agricultural services, and forestry and fishing/hunting/trapping. Data on physical output of some products are available from the Food and Agriculture Organization of the United Nations (FAO). However, matching energy-use data for the same products are rarely available, and thus it is difficult to construct disaggregated energy intensities from the physical output data.

Unit: Constant currency. The market value of output in the real national currency is deflated to a base year using GDP deflators. The national currency can be converted into US dollars, using purchasing power parity for the base year.

(c) Limitations of the Indicator: The aggregate indicator for the agricultural sector (ISIC, Division A, groups 01, 02, 07, 08 and 09) reflects the energy intensity for all agricultural activities (crop and livestock production, forestry, fishing, etc.). Changes in this aggregate indicator are due to changes in both energy efficiency and the product mix of agricultural output (structure). This means that differences seen across countries in both the absolute level and the time development of this indicator do not necessarily reflect differences in energy efficiency. Furthermore, agricultural production is affected by factors other than energy inputs (e.g. climate, availability of other inputs, etc). These factors are less distorting if comparative values are collected for consecutive years. Data for energy use in agriculture are not considered to be very reliable at the present time. Special surveys could generate sound data but would be expensive and might not be a priority for statistical agencies.

(d) Alternative Definitions/Indicators: An alternative indicator is energy use per unit of agricultural output. While data for production are available, it is problematic to find data on energy use disaggregated for specific forms of agricultural activity. The indicator includes combustible renewables and waste (CRW) but not such non-commercial energy inputs as human and animal power. Human power quantification methodologies might need to be further elaborated.

ASSESSMENT OF DATA

(a) Data Needed to Compile the Indicator:

- Total final energy use by the agricultural sector.
- Electricity consumption by the agricultural sector.
- Value added of the agricultural sector.

(b) National and International Data Availability and Sources: Some data are available for most countries, although reliable and comprehensive statistics to enable time-series analysis are elusive. Agriculture value-added data are compiled by the World Bank. Agricultural production figures are available from agriculture ministries. The FAO has processed and compiled considerable data on agricultural sector outputs in physical terms. The United Nations compiles value added at the two- and three-digit level in the agricultural sector. The energy balances of the International Energy Agency (IEA) include energy use in agriculture. Energy balances are prepared by energy ministries or other competent national authorities. Regional data are available from regional organizations such as the Organización Latinoamericana de Energía (OLADE).

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ECO8: Service/commercial energy intensities

Brief Definition	Final energy use per unit of service and commercial value added or per floor area
Units	Tonnes of oil equivalent (toe) for final energy and kilowatt-hours (kWh) for electricity per US dollar (value added), in constant US dollars (purchasing power parity [PPP]) or per square metre of floor area
Alternative Definitions	None
Agenda 21	Consumption and production patterns

POLICY RELEVANCE

(a) Purpose: This indicator is used to monitor trends in energy use in the service/ commercial sector.

(b) Relevance to Sustainable Development: The service sector is less energy intensive than is the manufacturing sector, and the growth of the sector relative to manufacturing contributes to the long-term reduction in the ratio of total energy use to gross domestic product (GDP). The sector, however, is a large consumer of electricity. In general, sustainable development requires increases in energy efficiency in all sectors in order to reduce overall energy use and to diminish negative environmental impacts.

(c) International Conventions and Agreements: There are no international agreements. Some countries are promulgating energy efficiency standards for lighting, office equipment or other devices, while others are negotiating voluntary agreements to reduce energy use per square metre of floor space.

(d) International Targets/Recommended Standards: There are no international targets or standards. Many industrialized countries have set targets for reducing the space-heating component of service-sector energy use per unit of floor area. Currently, many countries are trying to reduce electricity consumption for cooling, lighting and information systems.

(e) Linkages to Other Indicators: This indicator is part of a set for energy intensity in different sectors (manufacturing, transport, agriculture and residential), with the indicator for energy use per unit of GDP as an aggregate energy intensity indicator. This indicator is also linked to indicators for total energy and electricity use, greenhouse gas emissions and air pollutant emissions.

METHODOLOGICAL DESCRIPTION

(a) Underlying Definitions and Concepts: Energy use per unit of value added or per unit of floor area in the service/commercial sector is one way to measure energy requirements and trends of service buildings. These buildings include both public and commercial services such as offices, schools, hospitals, restaurants, warehouses and retail stores. Energy use in services is challenging to analyse in the aggregate owing to the large differences among building types and the wide range of activities and energy-related services offered in any given building. That buildings house different kinds of enterprises and a given branch of enterprises may be found in many different kinds of buildings makes the situation even more complex. Thus the service/commercial sub-sectors are diverse and difficult to classify. They include sub-sectors that require a great deal of electricity per unit of output (retail trade), those that use large quantities of fuel for water and space heating (health care establishments) and those that by their nature consume little energy (warehouses, parking garages). Energy efficiency in this sector is more directly related to the efficiency of general energy services (lighting, ventilation, computing, lifting, etc.) than to the efficiency of the particular sectoral activities. However, there are almost no data on actual energy service outputs per unit of energy input (lumens of light, cubic metres of air moved, computing power or use, tonnes raised in lifts, etc.). Hence, the usual measure of energy intensity, toe per unit of output in economic terms (toe /US dollar), can be a useful indicator, provided it is clear that this indicator summarizes many processes and types of buildings. Because of the differences in processes, it is very important to separate electricity from fossil-fuel and purchased heat.

Changes in intensities are affected by factors other than energy efficiency; therefore, analysing intensity trends provides important insights into how energy efficiency and other factors affect energy use. Annex 3 includes a decomposition method for energy intensities.

(b) Measuring Methods:

Energy Use: Energy use (including district heating and electricity) and electricity intensities are recorded separately. Final energy use is usually measured at the point of use (i.e. the building or enterprise). Data for enterprises in this sector are usually collected through the enterprise's normal accounting of expenditures or use of energy. Note, however, that the correspondence between enterprise and building type can be very loose.

In a few countries, energy use in buildings by type of end use is measured by surveys of actual buildings. Where these data exist, they can be used to construct more disaggregated intensities that better reflect efficiencies of certain end uses. Heating energy use per square metre of floor area heated is an important example of such a measure. Electricity use per square metre is important to measure, but it is difficult to disaggregate into heating, cooling, water heating/cooking, lighting, etc., without recourse to detailed surveys. Some colder countries (e.g. Norway) have a high overall energy intensity in the service sector and a high share of electric heating, while other colder countries (e.g. Finland) also have high intensities, but with much less electric space heating. Similarly, warmer countries have substantial amounts of space that are fully air-conditioned. For many countries, data on the amount of air-conditioned space are not available.

Despite all these uncertainties, fuel intensities give useful information about space- and water-heating and cooking activities, and electricity intensities for electricity services.

Units: toe for final energy and kWh for electricity.

Output: There are different approaches to measuring output in the service/commercial sector, with value added as the most direct measure of economic output. However, intensities calculated as energy per unit of floor area are more closely related to energy efficiency for end uses such as heating, cooling and lighting. Surveys of floor area, by building type, have been carried out in many International Energy Agency (IEA) Member countries. Often, the building type is specifically related to the activity of the enterprise — for example, school (education), hospital (health care) or restaurant (food services). However, in many cases, particularly for offices and restaurants, buildings contain a mix of activities and enterprises, each with its own energy system and with considerably different energy-use patterns.

Unit: Constant currency. The market value of output in the real national currency is deflated to a base year using GDP deflators. The national currency can be converted to US dollars, using PPP for the base year. For floor area, square metres of built space is usually the unit, but in some colder countries, square metres of occupied or heated space is recorded. The difference, which can be significant, reflects unheated spaces, garages and stairwells, etc.

(c) Limitations of the Indicator: It is often difficult to measure and interpret energy intensities per unit of value added within sub-sectors (private services, public services, etc.) because different activities often take place in the same building, hence the real allocation of energy use among activities is uncertain. In such cases, intensities expressed per unit area disaggregated by building type may be more easily related to real energy efficiencies. However, these have the similar problem that a variety of activities may take place in a particular type of building. A hospital, for example, will contain space for food preparation or laundry services, as well as for health care.

(d) Alternative Definitions/Indicators: None.

ASSESSMENT OF DATA

(a) Data Needed to Compile the Indicator:

- Energy use by service/commercial sector.
- Electricity consumption by service/commercial sector.
- Real value added of the sector.
- Built areas or occupied space (sometimes, heated space).

(b) National and International Data Availability and Sources: Data on value added or GDP in one-digit service sector branches of the International Standard Industrial Classification (ISIC) system are available for almost every country. More detailed data exist for Organisation for Economic Co-operation and Development (OECD) countries, both from national sources and from the OECD national accounts, as well as from the OECD's STAN database.

Energy-use data at the sector-wide level are available for almost all OECD countries and for most others, but there are some important caveats. First, one must check the residential sector data from the same source to determine whether liquid and solid fuels have been divided between these sectors (service/commercial and residential). In many of the IEA time series, this division is not made, and one sector or the other has all of the liquid or solid fuels. For developing countries, this split is a problem for gas as well, which is often entirely allocated to either residential use or services rather than being split. Second, it must be checked whether the service/commercial sector contains data from other sectors — for example, agriculture, construction, street lighting and even non-energy utilities like water and waste disposal.

Regional data are available from regional organizations such as the Asia Pacific Energy Research Centre (APERC) and the Organización Latinoamericana de Energía (OLADE).

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<u>ECO9:</u> Household energy intensities

Brief Definition	Amount of total residential energy used per person or household or unit of floor area. Amount of energy use by residential end use per person or household or unit of floor area, or per electric appliance
Units	Tonnes of oil equivalent (toe) of final energy and kilowatt-hours (kWh) of electricity per capita or per household or square metre of floor area; toe and kWh of electricity for space heating per unit of floor area; kWh of lighting per unit of floor area; toe and kWh for cooking per household; toe and kWh for water heating per capita; unit electricity consumption for electric appliances
Alternative Definitions	None
Agenda 21	Chapter 4: Consumption and production patterns

POLICY RELEVANCE

(a) Purpose: This indicator is used to monitor energy use in the household sector.

(b) Relevance to Sustainable Development: The household sector is a major user of energy with distinctive usage patterns. Improvement of energy efficiencies in this sector is an important priority for many countries, since it translates into the more effective utilization of energy resources and a reduction of negative environmental impacts. Many policies addressing energy efficiency and savings have been formulated for this sector. In colder countries, for example, the space-heating component has been the focus of many energy-saving policies, while in almost all countries, the electric-appliance and lighting component is still the focus of many policies.

(c) International Conventions and Agreements: None specifically for this sector.

(d) International Targets/Recommended Standards: There are no international targets or standards; however, thermal standards for new homes are in effect in almost all Organisation for Economic Co-operation and Development (OECD) and East European countries, and in other countries in colder climates. Efficiency standards for boilers and new electric appliances exist and are also important in many countries. Many countries have home energy standards for home appliances.

(e) Linkages to Other Indicators: This indicator is part of a set for energy intensities in different sectors (manufacturing, agriculture, transport and service/commercial), with the indicator for energy use per unit of gross domestic product (GDP) as an aggregate energy intensity indicator. These indicators are also linked to indicators of total energy and electricity use, greenhouse gas emissions and air pollutant emissions.

METHODOLOGICAL DESCRIPTION

(a) Underlying Definitions and Concepts: Household energy use encompasses energy used in residential buildings, including urban and rural free-standing houses, apartment dwellings and most collective dwellings such as dormitories and barracks. These energy uses typically include cooking, water heating, space heating and cooling, lighting, major appliances for refrigeration, washing and drying, television and communications, computers, conveniences like food processing machines, vacuum cleaners, etc., as well as a myriad of small appliances. Household energy use should exclude energy for farm processes, small businesses or small industry. The household sector must be separated from the service/commercial sector. The energy fuel options should include not only commercial energy, but also non-commercial energy sources such as fuelwood and other biomass fuels.

Changes in intensities are affected by factors other than energy efficiency; therefore, analysing intensity trends provides important insights into how energy efficiency and other factors affect energy use. Annex 3 includes a decomposition method for energy intensities.

(b) Measuring Methods:

Energy Use: Commercial energy for households is usually recorded in the energy statistics of countries based on data provided by electric, gas or heat utilities according to customer definitions that correspond to ‘households’. Data on purchases of liquefied petroleum gas (LPG), other oil products, coal or similar fuels and wood are not always recorded correctly since suppliers may not know where or how these fuels are being used.

More information on different end uses in the household sector can be obtained through household surveys. The most direct surveys collect detailed information on both fuels consumed and energy-using equipment owned or used. The most accurate surveys also collect data (with permission from households) from energy suppliers for quantities consumed, or they use fuel-use diaries for households to record what is consumed. The surveys measure usage in a variety of appliances and in heating equipment using miniature data loggers. Less-detailed surveys estimate the use of each fuel for each major purpose through regression analysis over a large number of households.

Unit: toe for final energy and kWh for electricity.

Activity: At the aggregate level, residential energy use is calculated on a per capita or per household basis, or if data are available, per unit of floor area. In general, energy use depends on both the physical size and characteristics of the dwelling, on the number of people and on ownership levels of electric appliances. As the number of people in a household declines, energy use per household declines, while the energy use per capita increases. Energy use for water heating and cooking, and for many appliances tends to vary with the household size and the number of people per household.

For developing countries with large rural sectors or large numbers of homes without access to electricity, the share of homes connected to the electricity grid is an important factor in total household energy use. The shares of homes using different kinds of combustible renewables and waste (CRW) are also important.

(c) Limitations of the Indicator: When energy use by end use is not known, energy use per household can be used as an energy-intensity indicator, but it does not measure energy efficiency developments very well. Some important conclusions can be drawn, however, if the average winter temperature, ownership of energy-using appliances and dwelling size are known. In a country with cold winters and a high penetration of central heating systems, a low total use of energy for all purposes, relative to total home (floor) area and the severity of winter climate, probably implies efficient heating practices. Conversely, high energy use relative to floor area in a country with mild winters might imply inefficiencies. However, since energy-use habits vary so much, both among countries and among end uses, few conclusions about efficiency can be drawn from the indicator on residential energy use per household.

The measurement and interpretation of energy intensities are complicated by differences among products within a category, such as size (e.g. refrigerator capacity), features (freezer compartments in refrigerators) and utilization (hours per year a stove is used).

(d) Alternative Definitions/Indicators: None.

(e) Measurement of Efficiency: To describe energy efficiency developments, intensities should be expressed as energy use per unit of disaggregated energy service. The inverse of these intensities would then reflect energy efficiency — for example, litres of refrigerated volume at a given temperature divided by electricity use for refrigeration, lumens of light per watt of power consumed, or computer tera-flops per second divided by power consumption for the computer, etc. In practice, these kinds of disaggregated data are not available. For some household equipment, specific energy requirements can be calculated from survey data on equipment efficiency and usage time per year for the equipment.

Activity (Services Provided): Ideally, output units would be in energy services delivered, such as lumens of lighting, number of meals cooked, area and time heated, litres of hot water provided, litres refrigerated, kilograms of clothes washed, etc. In practice such data are rarely available, even for individually metered homes. If data separating residential energy use by main end use are available, floor area should be used as the activity measure for space heating, air conditioning and lighting; number of persons per household, for water heating and cooking; and ownership levels measured as number of devices per household, for important electric household appliances.

Disaggregated Intensities: Using the activity measures mentioned above, the following intensities may be developed for each main end use:

- Space heating: energy use per square metre of heated floor area or per square metre per degree-day (this intensity should be measured in terms of useful energy, i.e. taking into account estimates of the efficiency of different space-heating alternatives).
- Energy use per capita for heating water and cooking.
- Electricity use per unit for each major appliance: refrigerator, freezer, clothes washer, clothes dryer, dishwasher, television, etc.

These specific energy requirements are related to, but not identical to, the inverse of energy efficiencies. However, these intensities are often the most disaggregated measures that can be constructed from statistics published regularly in Organisation for Economic Co-operation and Development (OECD) countries. Yet it should be noted that also many countries within the OECD do not estimate the split between residential end uses, and consequently even more aggregate measures, such as total residential energy per household, remain the only alternative.

ASSESSMENT OF DATA

(a) Data Needed to Compile the Indicator:

- Energy use by main residential end use (heating, cooling, cooking, heating water, lighting).
- Population and/or number of households.
- Area per household or per capita.
- Electricity use per major appliance (e.g. refrigerators, freezers, combination freezers/refrigerators, clothes washers, clothes dryers, dishwashers, televisions).

(b) National and International Data Availability and Sources: In some countries, the lack of separation between the residential/household and the service/commercial sectors in energy statistics has been a problem, particularly for liquid and solid fuels. In OECD countries, this distinction is now common. In developing countries, data often distinguish between residential and commercial consumption of electricity and natural gas, but users of liquid and solid fuels are often not accurately identified. Many national energy balances thus fail to distinguish between the residential and service/commercial sectors. Such problems are indicated when data show electricity and natural gas consumption for both the residential and service/commercial sectors, while liquid and solid fuel consumption is shown for only one of the two sectors.

The other major challenge is to estimate the use of all kinds of non-commercial fuels, such as CRW (biomass), in developing countries. This is important in almost all developing countries, even in urban areas. Because of these two problems, aggregate national or international statistics must be used with caution.

Consistent data separating residential energy use by main end uses are often not available, even in OECD countries, and have thus not been compiled by international institutions. However, both the International Energy Agency (IEA) and Eurostat have recently started collecting these data, where available, from their respective member countries. The World Bank has sponsored many one-time household surveys in developing countries, focusing either on rural or urban areas. In addition to survey results, data on energy-using equipment are sometimes available from electric and gas utilities, as well as from sales statistics from electric and gas appliance manufacturers.

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<u>ECO10:</u> Transport energy intensities

Brief Definition	Energy use per unit of freight-kilometre (km) hauled and per unit of passenger-km travelled by mode
Units	Freight: tonnes of oil equivalent (toe) per tonne-km Travel: toe per passenger-km
Alternative Definitions	Overall average fuel consumption for all modes per passenger-km or tonne-km
Agenda 21	Consumption and production patterns

POLICY RELEVANCE

(a) Purpose: Transport is a major user of energy, mostly in the form of oil products, which makes transport the most important driver behind growth in global oil demand. The transport indicators measure how much energy is used for moving both goods and people.

(b) Relevance to Sustainable Development: Transport serves economic and social development through the distribution of goods and services and through personal mobility. However, energy use for transport also leads to the depletion of resources and to air pollution and climate change. Reducing energy intensity in transport can reduce the environmental impacts of transport while maintaining the economic and social benefits.

(c) International Conventions and Agreements: There are no international conventions directly related to energy intensities in the transport sector. International conventions on energy emissions, such as the United Nations Framework Convention on Climate Change (UNFCCC) and its Kyoto Protocol, are indirectly related to transport energy intensities. The European Union voluntary commitments on carbon dioxide (CO_2) emissions by European, Japanese and Korean car manufacturer associations require reductions of CO_2 emissions per kilometre for new automobiles.

(d) International Targets/Recommended Standards: Many industrialized countries have targets for reducing energy use and carbon emissions from transport.

(e) Linkages to Other Indicators: This indicator is part of a set for energy intensities in different sectors (manufacturing, agriculture, service/commercial and residential), with energy use per unit of gross domestic product (GDP) as an aggregate energy intensity indicator. These indicators are also linked to indicators for total energy use, greenhouse gas emissions and air pollution emissions.

METHODOLOGICAL DESCRIPTION

(a) Underlying Definitions and Concepts: The transport indicators reflect how much energy is used to transport goods and people. The separation of freight transport and passenger travel is essential for energy analysis, both because they are largely based on different modes and because the activities driving energy use are different. The two activity measures (tonne-km and passenger-km) are quite distinct and are collected separately. However, separating the energy use in these two activities is often complicated given the way data are available from typical energy statistics.

Changes in intensities are affected by factors other than energy efficiency; therefore, analysing intensity trends provides important insights into how energy efficiency and other factors affect energy use. Annex 3 includes a decomposition method for energy intensities.

(b) Measuring Methods:

Energy Use: Ideally, for road transport, energy use should be measured for each type of vehicle or *means of transport*, including two-wheel vehicles, automobiles, sport utility vehicles (SUVs) and buses for personal travel, and small trucks, heavy trucks and miscellaneous road vehicles for freight transport. Outside of road transport, both freight and personal travel should be divided into trains, ships and aircraft for domestic transport. In general, however, national energy balances are only disaggregated by fuel and broad traffic type or *mode of transport*: road, rail, water, air and pipeline. Thus, they give no information on energy use by individual means of road transport or, even more importantly, on the split between personal travel and freight transport. International air or maritime transport should not be included.

Output or Activity: For assessing the efficiency of road vehicles, vehicle-km is a useful activity measure, assuming that data are available for each vehicle type. However, to be able to construct indicators across all modes for personal travel and freight transport, passenger-km and tonne-km, respectively, must be used as activity variables. This also provides a better indication of how efficiently energy is used to provide personal mobility and distribution of goods. For example, from this perspective, a bus carrying 20 passengers for 10 km (200 passenger-km) is less energy intensive (more efficient) than the same bus carrying 5 passengers for the same distance (50 passenger-km). Similarly, a fully loaded truck is less energy intensive than the same truck carrying a partial load.

Vehicle Intensities: Energy use per vehicle-km by vehicle and fuel type is an important indicator, as many standards for air pollution (and more recently, goals for CO_2 emissions reductions) are expressed in terms of vehicle characteristics, that is, emissions per vehicle-km.

Modal Intensities: Energy use per passenger-km or tonne-km should be disaggregated by vehicle type, namely, two-wheel vehicle, automobile/van, bus, airplane, local and long-distance train, metro (also known as 'subway' or 'underground'), tram, ship or ferry for passengers, and truck, train, ship or airplane for freight.

Note: Aggregate energy intensities for travel or freight are a meaningful summary indicator whose value depends on both the mix of vehicles and the energy intensities of particular types of vehicles. The energy intensities of public train and bus transport per passenger-km are significantly lower than the energy intensities for automobiles or air transport. Freight, rail and ship transport are commonly less energy intensive than is trucking per tonne-km. It should also be noted that fuel consumption per vehicle-km also depends on traffic conditions as well as vehicle characteristics.

The energy intensity of a vehicle depends on both capacity and capacity utilization. A large vehicle that is fully loaded generally has lower energy intensity per tonne-km than a fully loaded smaller vehicle, but a small vehicle fully loaded will have a lower energy intensity than a large vehicle with the same load.

For some developed countries, typical load factors for private automobiles are 1.5 persons per automobile. For rail and bus, load factors vary from well below 10% (e.g. United States city buses on average) to over 100% of nominal capacity at peak times (in many developing countries during most of the day). Typical load factors for trucking might be 60–80% of weight capacity when loaded, but trucks commonly run 20–45% of their kilometres empty, yielding a relatively low overall load factor. Underutilized transport capacity means more pollution and road damage per unit of transport service delivered; hence capacity utilization itself is an important indicator of sustainable transport.

(c) Limitations of the Indicator: Data availability may limit the disaggregation of the indicator to the desired level. Considerable work is often required to disaggregate energy balances into various modes of transport.

Some countries' transport energy statistics include fuel consumed by domestic airlines or shipping lines in international transport. Efforts should be made to exclude such transport and energy use from the indicators.

Measurement and interpretation of energy intensities are complicated by differences among products within a category, such as size (e.g. automobile weight), features (power steering and automatic transmission in automobiles) and utilization (vehicle occupancy if passenger-km is the measure of output).

(d) Alternative Definitions/Indicators: An alternative, simpler measure of energy intensity for transport could be overall average fuel consumption per passenger-km or tonne-km for all modes, but the results would be strongly influenced by the mix of modes and vehicle types, which varies enormously among countries and over time.

ASSESSMENT OF DATA

(a) Data Needed to Compile the Indicator:

- Energy use by mode of transport, vehicle type and fuel for passenger travel and freight transport separately.
- Distance travelled by vehicles, passengers and freight, including load factors.
- Distance travelled by urban public transport and corresponding share of electric vehicles.

(b) National and International Data Availability and Sources: National energy balances and energy statistics from the International Energy Agency (IEA) and Eurostat normally do not disaggregate road transport into individual means of transport, but this information is sometimes published by transport ministries. Few sources of energy data separate fuel consumption for air, rail or domestic shipping into that for passengers and that for freight, but national or private rail and shipping organizations may have this information. Energy use for local electric transport (commuter rail, metro, trams) is often published separately by national authorities.

Eurostat, the European Conference of Ministers of Transport (ECMT) and the United Nations Economic Commission for Europe (UNECE) are leading agencies for the collection of data on vehicle-, passenger- and tonne-km in Europe. Transport ministries in the United States, Canada, Japan, Australia and other countries publish similar data, often through their statistical agencies. In developing and transitional countries, fewer data are available.

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ECO11: Fuel shares in energy and electricity

Brief Definition	The structure of energy supply in terms of shares of energy fuels in total primary energy supply (TPES), total final consumption (TFC) and electricity generation and generating capacity
Units	Percentage
Alternative Definitions	None
Agenda 21	Chapter 4: Changing consumption and production patterns

POLICY RELEVANCE

(a) Purpose: This indicator provides the share of fuels in TPES, TFC and electricity generation and generating capacity.

(b) Relevance to Sustainable Development: Regarding the economic dimension, the energy supply mix is a key determinant of energy security. Therefore, the ‘right’ energy mix for a particular country relies on a well-diversified portfolio of domestic and imported or regionally traded fuels and sources of energy. Also, the particular mix of fuels used in energy and electricity affects energy intensities.

With respect to the environmental dimension, the energy supply mix has a major effect since the environmental impacts of each energy source differ greatly and include the following: (i) traditional local or regional atmospheric pollution related to the combustion of fossil fuels (e.g. urban smog, acid rain); (ii) global climate change related to the emission of greenhouse gases (GHGs) generated by fossil fuel production, transport and use; (iii) land use for a range of energy activities, and notably for mining and for hydroelectric reservoirs; and (iv) risks attributed to various fuel chain cycles (fires, explosions, spills, radioactive emissions, etc.).

(c) International Conventions and Agreements: None.

(d) International Targets/Recommended Standards: In some countries there is a target for the percentage of electricity from renewable sources. For example, in the European Union a directive sets the quantitative target of 21% for electricity from renewable energy by the year 2010, as well as indicative targets for each Member State.

(e) Linkages to Other Indicators: This indicator is linked to annual indigenous fuel production, annual energy use per capita, net energy import dependence and lifetime of proven energy reserves. It is also closely linked to some of the environmental indicators, such as air pollutants and GHG emissions, generation of solid and radioactive wastes, land area taken by energy facilities, etc.

METHODOLOGICAL DESCRIPTION

(a) Underlying Definitions and Concepts: This indicator disaggregates energy supply by fuel source with respect to TPES, TFC and electricity generation and generating capacity. The components of this indicator are consumption of various fossil fuels (coal, crude oil, petroleum products, gas); primary electricity and heat; non-combustible renewables; and combustible renewables and waste (CRW).

Regarding the primary energy supply mix, sources to be specified are coal, crude oil, gas, nuclear power, hydropower, non-combustible renewables, CRW and net import of electricity.

Regarding the final energy use mix, sources to be specified are coal, crude oil, petroleum products, gas, electricity, heat and CRW.

Regarding electricity generation and generating capacity, sources to be specified are coal, petroleum products, gas, nuclear, hydropower, non-combustible renewables and CRW.

(b) Measuring Methods: This indicator is computed by calculating the ratio of consumption or production of the specific energy fuels identified above to total energy use or production with respect to:

- TPES,
- TFC and
- Electricity generation.

Energy use is measured in terms of heat contents based on their specific net calorific values (NCVs).

For electricity generating capacity, the indicator corresponds to the shares of capacity by fuel.

(c) Limitations of the Indicator: Data on particular fuels for a number of developing countries might be a limitation.

(d) Alternative Definitions/Indicators: None.

ASSESSMENT OF DATA

(a) Data Needed to Compile the Indicator:

- Primary energy supply, TPES and by specified primary energy fuels.
- Final energy use, TFC and by specified final energy fuel consumption.
- Electricity generation, total and by fuel.
- Generating capacity, total and by fuel.

(b) National and International Data Availability: Data on energy supply by fuel are available from national statistical offices and country publications, and various international sources, such as the International Energy Agency (IEA), the World Bank, Eurostat and the United Nations.

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<u>ECO12:</u> Non-carbon energy share in energy and electricity

Brief Definition	The share of non-carbon energy sources in primary energy supply (TPES) and in electricity generation and generating capacity
Units	Percentage
Alternative Definitions	None
Agenda 21	Chapter 4: Changing consumption and production patterns

POLICY RELEVANCE

(a) Purpose: This indicator measures the share of non-carbon energy sources in TPES and electricity generation and generating capacity.

(b) Relevance to Sustainable Development: The promotion of energy and of electricity from non-carbon sources is a high priority for sustainable development for several reasons, ranging from environmental protection to the energy security and diversification of energy supply. An increase in the share of non-carbon fuels reduces the specific emissions — that is, emissions per unit of total energy and electricity used — of greenhouse gases (GHGs) and other pollutants affecting local air quality and regional acidification. The introduction of carbon taxes targets, to a large extent, a shift towards a higher share of non-carbon energy sources in the primary energy mix.

(c) International Conventions and Agreements: None.

(d) International Targets/Recommended Standards: At the World Summit on Sustainable Development in Johannesburg in 2002, an agreement was reached to increase the global share of renewable energy sources. In some countries, there is a target for a certain percentage of energy supply from renewable sources. For example, in the European Union a directive sets quantitative targets for electricity from renewable energy to be 21% by the year 2010, as well as indicative targets for each Member State.

(e) Linkages to Other Indicators: This indicator is linked to fuel shares (energy mix) and shares of renewables in energy and electricity. The indicator is also linked to indicators of energy use and electricity generation and to environmental indicators such as GHGs, etc.

METHODOLOGICAL DESCRIPTION

(a) Underlying Definitions and Concepts: This indicator is an aggregation of non-carbon energy sources with respect to TPES and electricity generation and generating capacity.

Non-carbon energy sources include combustible and non-combustible renewables and nuclear electricity generation.

(b) Measuring Methods: The share of non-carbon energy sources in TPES is the primary supply of non-carbon energy divided by TPES. The share of non-carbon energy in electricity generation is the total electricity generated from non-carbon energy sources divided by total electricity generation.

Energy use is measured in terms of heat content based on specific net calorific values (NCVs).

Electricity from hydropower and other non-combustible renewables (such as wind, tide, photovoltaics, etc.) is accounted for by using the factor 1 terawatt hour (TWh) equals 0.086 million tonnes of oil equivalent (Mtoe). Electricity from nuclear power is accounted based on an average thermal efficiency of 33%; that is, 1 TWh equals 0.261 Mtoe (see Annex 1).

For electricity generating capacity, the indicator corresponds to the shares of non-carbon energy in overall capacity.

(c) Limitations of the Indicator: For a number of countries, data on non-carbon energy sources might be a limitation.

(d) Alternative Definitions/Indicators: None.

ASSESSMENT OF DATA

(a) Data Needed to Compile the Indicator: TPES and total electricity generation and generating capacity. Primary energy from non-carbon energy options, and electricity generation and generating capacity from renewable and nuclear sources.

(b) National and International Data Availability: Data on energy supply by fuel are available from national statistical offices and country publications, and various international sources, such as the International Energy Agency (IEA), the International Atomic Energy Agency (IAEA), the World Bank and Eurostat.

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- World Bank, various editions. *World Development Indicators.* Published annually. Washington DC, USA: World Bank.

ECO13: Renewable energy share in energy and electricity

Brief Definition	The share of renewable energy in total primary energy supply (TPES), total final consumption (TFC) and electricity generation and generating capacity (excluding non-commercial energy)
Units	Percentage
Alternative Definitions	None
Agenda 21	Chapter 4: Changing consumption and production patterns

POLICY RELEVANCE

(a) Purpose: This indicator measures the share of renewable energy in TPES, TFC and electricity generation and generating capacity.

(b) Relevance to Sustainable Development: The promotion of energy, and in particular of electricity from renewable sources of energy, is a high priority for sustainable development for several reasons, including the security and diversification of energy supply and environmental protection.

(c) International Conventions and Agreements: None.

(d) International Targets/Recommended Standards: At the World Summit on Sustainable Development in Johannesburg in 2002, an agreement was reached to increase urgently and substantially the global share of renewable energy sources. A coalition was formed at the Summit that includes countries and regions willing to set themselves targets and time frames for the increase of renewable energy sources in the energy mix. More than 80 countries are now members of this coalition. Also, in some countries there is a target for the percentage of electricity from renewable sources. For example, in the European Union a directive sets the quantitative target of 21% for electricity from renewable energy by the year 2010, as well as indicative targets for each Member State.

(e) Linkages to Other Indicators: This indicator is linked to fuel shares (energy mix) in energy and electricity and non-carbon fuel shares. Also, the indicator is linked to indicators related to security of supplies and environmental protection.

METHODOLOGICAL DESCRIPTION

(a) Underlying Definitions and Concepts: This indicator aggregates renewable energy options with respect to TPES, TFC and electricity generation and generating capacity.

Renewable energy includes both combustible and non-combustible renewables.

Non-combustible renewables include geothermal, solar, wind, hydro, tide and wave energy. For geothermal energy, the energy quantity is the enthalpy of the geothermal heat entering the process. For solar, wind, hydro, tide and wave energy, the quantities entering electricity generation are equal to the electrical energy generated. Electricity is accounted for at the same heat value as electricity in final consumption (i.e. 1 terawatt hour [TWh] equals 0.086 million tonnes of oil equivalent [Mtoe]). Direct use of geothermal and solar heat and heat from heat pumps is also included.

The combustible renewables and waste (CRW) consist of biomass (fuelwood, vegetal waste, ethanol) and animal products (animal materials/wastes and sulphite lyes), municipal waste (wastes produced by the residential, commercial and public service sectors that are collected by local authorities for disposal in a central location for the production of heat and/or power) and industrial waste.

(b) Measuring Methods: This indicator is computed by calculating the ratio of the consumption and production of renewables to total final energy supply and production.

The share of renewables in electricity is the electricity generated from renewables divided by total electricity use.

Energy use is measured in terms of heat content based on specific net calorific values (NCVs).

For electricity generating capacity, the indicator corresponds to the shares of renewables in overall capacity.

(c) Limitations of the Indicator: Data on particular renewables for a number of developing countries might be a limitation.

(d) Alternative Definitions/Indicators: None.

ASSESSMENT OF DATA

(a) Data Needed to Compile the Indicator: TPES, TFC, total electricity generation and generating capacity. Primary energy from renewable energy options, electricity generation and generating capacity from renewable energy options.

(b) National and International Data Availability: Data on energy supply by fuel are available from national statistical offices and country publications, and from various international sources, such as the International Energy Agency (IEA), the World Bank and Eurostat.

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- World Bank, various editions. *World Development Indicators.* Published annually. Washington DC, USA: World Bank.

ECO14: End-use energy prices by fuel and by sector

Brief Definition	Actual prices paid by final consumer for energy with and without taxes and subsidies
Units	US dollars (purchasing power parity [PPP]) per unit of energy (different units)
Alternative Definitions	None
Agenda 21	Chapter 4: Consumption and production patterns

POLICY RELEVANCE

(a) Purpose: This indicator reflects the final price paid by consumers for energy services. Energy prices are driving forces for incentives or disincentives for consumption or conservation, or efficiency improvements. Also, prices can affect affordability.

(b) Relevance to Sustainable Development: Energy prices can be regulated to internalize environmental and social costs, to manage demand and to encourage development of alternative renewable energy options.

For developing countries, there is a need to increase energy availability and affordability, in particular for the lower-income groups of the population, so as to improve social and economic development. At the same time, efficient energy use in developing and developed countries is a major priority. Appropriate pricing mechanisms may be used to overcome inefficiencies.

(c) International Conventions and Agreements: None.

(d) International Targets/Recommended Standards: No international targets have been established. However, it is widely accepted that external costs of energy production and use should be internalized. Furthermore, the Johannesburg Plan of Implementation agreed at the World Summit on Sustainable Development calls for a phasing-out of environmentally harmful subsidies.

(e) Linkages to Other Indicators: Related indicators of the economic dimension are annual energy use per capita, intensity of energy use, energy mix and emissions of greenhouse gases. This indicator is also linked to social indicators such as share of household income spent on fuel and electricity.

METHODOLOGICAL DESCRIPTION

(a) Underlying Definitions and Concepts: This indicator reflects the actual price paid by final consumers for various energy services. Prices should include all regular charges linked to the supply of energy to the customer. For example, for electricity and gas, the data should include not only the price per kilowatt-hour (kWh) or cubic metre, but also any standing charges and meter rental charges. Initial charges for connection to the electricity or gas network should not be included. For other products, any delivery charge should be included. Energy prices can also be adjusted (e.g. through taxes) to incorporate external environmental and social costs that energy producers and consumers impose on others without paying the consequences. Examples of external costs include the environmental and health impacts of air, waste and water pollution, and climate change. Reflecting the cost of these impacts in the price of energy can help to promote more efficient energy supply and use.

Different prices are often charged to different types of consumer. Therefore, price data should be collected both for the main fuels and for different types of consumer — for example, households or industry.

An underlying principle of tracking price data over time is that the product for which the price is tracked remains the same throughout the period. This is clear in the case of gasoline, where the data to be collected is always the price at the pump of 1 litre or gallon of gasoline. However, for other products, such as electricity or gas, it is less straightforward, as the price per kWh paid will vary depending on the amount delivered. Therefore, it is necessary to define one or more standard consumers, representative of consumers in a given country, whose consumption pattern does not vary from one year to another, in order to track changes in price paid.

(b) Measuring Methods: Because prices change through the year, the data collected must refer to a fixed date; 1 January of each year is proposed.

Three price levels should be distinguished: prices including all taxes; prices excluding deductible taxes (normally only deductible for industry); and prices excluding all taxes. If possible, subsidies for different consumers should also be identified, though in practice this can prove to be extremely difficult, as the subsidies are often hidden in complicated tariff systems.

In general, prices are collected in national currencies and can be converted to a common unit, usually US dollars. Exceptions would be fuels such as aviation fuel, which is often billed directly in US dollars. A further refinement is to deflate prices to allow for inflation. In order to deflate the price series, the consumer price indices should be used for household prices, including pump prices of gasoline and diesel, and the industrial price indices (or gross domestic product [GDP], if industrial indices are not available) should be used for industrial prices.

Prices should be collected for the following products, in so far as these are commonly available on the market in the country:

Petroleum Products:

- Automotive fuel:
  - Premium unleaded gasoline.
  - Premium leaded gasoline.
  - Automotive gasoil (diesel).
- Heavy fuel oil (residual fuel oil), for industry.
- Light fuel oil (heating gasoil), for households.

- Kerosene, for households.
- Liquefied petroleum gas (LPG), for households.

Measurement: Average price charged by the main distributors on 1 January.

Prices for gasoline and diesel should be pump prices. For heating gasoil and residual fuel oil, a standard offtakes or delivery must be defined, as in general the unit price is lower for larger deliveries. Standard offtakes should be defined for domestic consumers and for industrial consumers. For example, in the countries of the European Union, prices are collected for the following:

- Heating gasoil: deliveries of 2000–5000 litres.
- Heavy fuel oil: offtakes less than 2000 tonnes per month or less than 24 000 tonnes per year.

Coal:

- Steam coal, for industry and for households.
- Coking coal, for industry.

Measurement: In many countries, the main users of coal are electricity generators and the steel industry. These users often directly import coal to meet their own needs, in which case it is sufficient to collect data on coal import prices.

Electricity, District Heat and Piped Gas:

- Electricity, for industry and for households.
- Natural gas, for industry and for households.
- Heat, for industry and for households.

Measurement: Average prices charged by main distributors on 1 January.

For electricity, heat and gas, a similar alternative is to use industry and household surveys to collect information on quantities of electricity, heat and gas purchased and amounts charged, and to calculate average expenditure per unit purchased. This is strictly speaking not a true price, but rather a weighted price, where the weighting varies from one year to another. However, it is preferable to the average revenue method.

The average revenue method, commonly used for lack of a better alternative, is based on data from utilities on average revenue per unit delivered. However, it is generally not possible to distinguish between sales to domestic and industrial customers, and data are skewed towards industry as the major consumers. Moreover, revenue data often include charges for connecting new customers to the network and for repairs, as well as income from sales of appliances.

(c) Limitations of the Indicator: The wide variety of energy products available on the market means a large number of prices need to be collected. For example, for road transport, leaded and unleaded 95 octane petrol, leaded and unleaded 98 octane petrol, diesel fuel, liquefied petroleum gas (LPG) and liquefied natural gas can all be found on the market. Normally, only a selection of those considered most representative can be taken into account.

Further problems include differing prices for different locations throughout the country; for example, prices in remote rural areas are often much higher than in major cities. As mentioned above, for some forms of energy, in particular electricity and gas, the price per unit will depend on a variety of delivery conditions. The indicator can therefore only be indicative of the price paid by a typical or standard consumer and cannot reflect the full spectrum of consumer types and locations.

(d) Alternative Definitions/Indicators: In practice, the method proposed above might prove difficult for an industry when no 'list price' exists and when industries negotiate individual supply contracts with the coal producer or oil company. In this case, the only solution is to carry out a sample survey of industry costs and to calculate average unit prices defined as total cost/quantity purchased.

ASSESSMENT OF DATA

(a) Data Needed to Compile the Indicator: Energy prices.

(b) National and International Data Availability: For coal and petroleum products, except aviation fuel, prices are generally available for developed countries, both nationally and internationally (Organisation for Economic Co-operation and Development [OECD], Eurostat). For gas and electricity, the availability of price data varies from country to country.

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<u>ECO15:</u> Net energy import dependency

Brief Definition	The ratio of net import to total primary energy supply (TPES) in a given year in total and by fuel type such as oil and petroleum products, gas, coal and electricity
Units	Percentage
Alternative Definitions	Net energy imports
Agenda 21	Chapter 4: Consumption and production patterns

POLICY RELEVANCE

(a) Purpose: This indicator measures the extent to which a country relies on imports to meet its energy requirements.

(b) Relevance to Sustainable Development: Maintaining a stable supply of energy is a core objective of policy in the pursuit of sustainable development. The importance of energy security in terms of the physical availability of supplies to satisfy demand at a given price for economic and social sustainability is paramount. Therefore energy supply interruptions constitute a type of systematic risk that needs to be addressed by policies for sustainable development. Two different kinds of risk are involved: a quantity risk and a price risk. Both risks are related to the level of a country's reliance on imported energy. Thus, the general exposure to energy supply disruptions can be limited by decreasing the import dependency, which in turn could be achieved through policies to increase indigenous energy production, enhance energy efficiency, diversify fuel sources, optimize fuel mix, etc.

(c) International Conventions and Agreements: None.

(d) International Targets/Recommended Standards: In some countries there is a recommended level to which a country may rely on energy import.

(e) Linkages to Other Indicators: This indicator is closely linked to some of the economic indicators, such as indigenous energy production, energy use per capita, etc. It is also linked to indicators of resource availability.

METHODOLOGICAL DESCRIPTION

(a) Underlying Definitions and Concepts: The elements that constitute this indicator are primary energy supply and fuel requirements (oil, gas, coal, etc.), and electricity.

Net energy import is calculated as imports minus exports, both measured in oil equivalents. Imports and exports are the amounts that have crossed the national territorial boundaries of a given country, whether or not customs clearance has taken place. A negative value for net imports indicates that the country is a net exporter.

Oil: Quantities of crude oil and petroleum products imported or exported under processing agreements (i.e. refining on account) are included. Quantities of oil in transit are excluded. Crude oil, natural gas liquids (NGL) and natural gas are reported as coming from the country of origin; refinery feedstocks and petroleum products are reported as coming from the country of last consignment.

Re-exports of oil imported for processing within the country are shown as exports of products from the processing country to the final destination.

Coal: Imports and exports are the amount of fuels obtained from or supplied to other countries, whether or not there is an economic or customs union between the relevant countries. Coal in transit is not included.

Electricity: Amounts are considered as imported or exported when they have crossed the national territorial boundaries of a given country.

If accurate data are not available on imports and exports, then net imports can be estimated as energy use less production, both measured in oil equivalents.

(b) Measuring Methods: This indicator is computed by calculating the ratio of net imports to consumption if the country is a net importer, or the ratio of exports to production if the country is a net exporter.

The indicator is computed for primary energy, in total and by fuel and electricity.

(c) Limitations of the Indicator: Data on imports for a number of fuels may not be readily available in some countries.

(d) Alternative Definitions/Indicators: Net energy imports.

ASSESSMENT OF DATA

(a) Data Needed to Compile the Indicator:

- Total primary and final energy use, imports, exports, production and by fuel — oil, gas, coal, etc.
- Electricity imports, exports, consumption and generation.

(b) National and International Data Availability: Data on energy imports, exports, production and use by fuel are available from national statistical offices and country publications and from various international sources, such as the International Energy Agency (IEA) and the World Bank.

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ECO16: Stocks of critical fuels per corresponding fuel consumption

Brief Definition	Ratio of the stocks of critical energy fuels to the daily, monthly or annual use of the corresponding fuel. Critical fuel is usually oil. Some countries might consider other fuels critical (e.g. natural gas, ethanol, etc.)
Units	Percentage
Alternative Definitions	Total fuel stocks
Agenda 21	Chapter 4: Consumption and production patterns

POLICY RELEVANCE

(a) Purpose: The purpose of this indicator is to measure the availability of national stocks of critical fuels, such as oil, with respect to corresponding fuel consumption. Many countries maintain stocks of oil in anticipation of disruptions in oil supply. For some countries, the critical fuel might be natural gas or other types of fuel. For example, ethanol is a critical fuel for the Brazilian transportation sector. The indicator provides a relative measure of the length of time that stocks would last if supply were disrupted and fuel use were to continue at current levels.

(b) Relevance to Sustainable Development: The availability and security of fuel supplies are key aspects of sustainability. This indicator provides a basis for estimating energy supply security by indicating the relation between the current availability of critical fuel stocks and levels of consumption. Maintaining strategic stocks of critical fuels might be a necessary component of a national sustainable energy programme. Fuel stocks over fuel consumption represents a type of ‘response’ indicator that might be important to countries in critical fuel supply situations, such as a world oil crisis, disruptions of natural gas distribution systems, etc.

(c) International Conventions and Agreements: The Member countries of the International Energy Agency (IEA) maintain minimum levels of oil stocks based on specific agreements.

(d) International Targets/Recommended Standards: The IEA provides recommended levels of oil stocks to its Member countries.

(e) Linkages to Other Indicators: This indicator is linked to indicators of annual energy production, annual energy use, imports, prices and resources.

METHODOLOGICAL DESCRIPTION

(a) Underlying Definitions and Concepts: Stocks of critical fuels, in particular oil, and the corresponding annual consumption provide an indication of energy supply security. Countries decide the appropriate levels of stocks of the critical fuels needed.

(b) Measuring Methods: This indicator is defined by dividing the stocks of the critical fuels maintained by countries by the corresponding daily, monthly or annual fuel consumption.

(c) Limitations of the Indicator: The rate of use of fuels, in particular oil, depends on many factors, including economic conditions, prices and technological progress. Therefore, this indicator represents only a relative measure of energy supply security. Many countries still cannot afford to maintain adequate levels of stocks of critical fuels.

(d) Alternative Definitions/Indicators: Total stocks of critical fuels.

ASSESSMENT OF DATA

(a) Data Needed to Compile the Indicator: Data on stocks of critical fuels and the corresponding annual consumption.

(b) National and International Data Availability: Data on stocks of critical fuels and the corresponding annual consumption are available from national energy and statistics bodies and for Organisation for Economic Co-operation and Development (OECD) countries from the IEA.

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ENVIRONMENTAL DIMENSION

ENV1: Greenhouse gas (GHG) emissions from energy production and use, per capita and per unit of GDP

Brief Definition	Emissions of greenhouse gases (GHGs) from energy production and use, per capita and per unit of gross domestic product (GDP), including carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O)
Units	Annual GHG emissions in tonnes, per capita or per US dollar. Emissions of CH_4 and N_2O are to be converted to CO_2 equivalents using the 100-year global warming potentials (GWPs) provided in the Intergovernmental Panel on Climate Change (IPCC) *Second Assessment Report* (1995)
Alternative Definitions	Total GHG emissions from energy production and use. GHG emissions from energy-related activities per unit of energy and electricity produced
Agenda 21	Chapter 9: Protection of the atmosphere

POLICY RELEVANCE

(a) Purpose: This indicator measures the total, the per capita and the per unit of GDP emissions of the three main GHGs from energy production and use that have a direct impact on climate change.

(b) Relevance to Sustainable Development: During the 20th century, the Earth's average surface temperature rose by around 0.6°C, and evidence is growing that most of this warming is attributable to increasing concentrations of GHGs in the atmosphere. The amount of CO_2, for example, has increased by more than 30% since preindustrial times and is currently increasing at an unprecedented rate of about 0.4% per year, mainly due to the combustion of fossil fuels and deforestation. The concentrations of CH_4 and N_2O are increasing as well due to energy, agricultural, industrial and other activities. The concentrations of nitrogen monoxide (NO), nitrogen dioxide (NO_2), carbon monoxide (CO) and non-methane volatile organic compounds (NMVOCs) are also increasing as a result of anthropogenic activity. Although these gases are not themselves GHGs, they affect atmospheric chemistry, leading to an increase in tropospheric ozone, which is a GHG.

The resulting effect is predicted to lead to more extreme weather events than in the past, with some areas experiencing increased storms and rainfall, and others suffering drought. How fast and where this change will happen is still uncertain, but the consequences may be serious, especially in developing countries, which are the least able to prepare for and deal with the effects of extreme weather conditions such as floods, landslides, droughts, etc.

(c) International Conventions and Agreements: The United Nations Framework Convention on Climate Change (UNFCCC) entered into force in March 1994. The Convention included a commitment by Parties, both developed countries and economies in transition (Annex I Parties), to aim to return emissions of CO_2 and other GHGs not controlled by the Montreal Protocol to their 1990 levels by 2000, although relatively few Parties actually met this goal. The Kyoto Protocol was adopted in December 1997. It was designed to enter into force after being ratified by at least 55 Parties to the Convention, including developed countries accounting for at least 55% of the total 1990 CO_2 emissions from this group. With the 2004 decision by the Russian Federation to ratify the Protocol, it entered into force in early 2005. In any event, countries are also bound by their commitments under the Convention.

Ozone-depleting GHGs are controlled by the Vienna Convention and the Montreal Protocol.

(d) International Targets/Recommended Standards: The Kyoto Protocol sets targets for each Annex I Party with a view to reducing these Parties' overall emissions of the six main GHGs by at least 5% below 1990 levels in the commitment period 2008–2012.

(e) Linkages to Other Indicators: This indicator is closely linked to many other economic and environmental indicators, including energy use per capita and per unit of GDP, primary and final energy use and electricity generation, fuel mix, atmospheric emissions, etc.

METHODOLOGICAL DESCRIPTION

(a) Underlying Definitions and Concepts: GHGs contribute in varying degrees to global warming depending on their heat absorption capacity and their lifetime in the atmosphere. The GWP describes the cumulative radiative forcing effect of a gas over a time horizon (usually chosen for reporting purposes to be 100 years) compared with that of CO_2. For example, the 100-year GWP of CH_4 is 21, meaning that the global warming impact of 1 kilogram (kg) of CH_4 is 21 times higher than that of 1 kg of CO_2. The GWP of N_2O is 310. No GWPs are provided for indirect GHGs. Sinks for GHGs should not be included in the indicator. There are currently no agreed international inventory methodologies for the quantification of engineered sinks in which energy-related GHG emissions can potentially be captured and stored, while biological sinks are not directly linked with energy-related GHG emissions.

(b) Measuring Methods: CO_2 emissions from fuel combustion are calculated by multiplying the energy use for each fuel type by an associated CO_2 emission coefficient. Wherever possible, GHG emissions should be measured directly at the source of energy use. More commonly, however, measured data are incomplete or unavailable. In the absence of measured data, emissions are calculated by multiplying some known data, such as coal production or natural gas throughput, by an associated emission factor derived from a small sample from a relevant emission source or through laboratory experiments.

(c) Limitations of the Indicator: This indicator shows the quantity of GHGs emitted into the atmosphere from energy use only. For some GHGs (e.g. N_2O), non-energy sources (e.g. agriculture) can produce significant levels of emissions. This indicator does not show how much the climate will be affected by the increased accumulation of GHGs or the consequent effect of climate change on countries. Data might not be available for some sources in some countries.

(d) Alternative Definitions/Indicators: Total quantities of annual GHG emissions or GHG emissions normalized per unit of energy use could be alternative indicators. This analysis would provide an indication of the trend of increasing or decreasing carbonization of the energy system. There are a number of other gases resulting from energy use that indirectly produce GHGs, and these could also be included in the scope of the definition.

ASSESSMENT OF DATA

(a) Data Needed to Compile the Indicator: Data on total GHG emissions from energy sources and the breakdown by component:

- CO_2, CH_4 and N_2O emissions.
- GHG emissions from energy production and use.
- GHG emissions from transportation.
- Total population for normalization of total GHG emissions per capita, unit: tonnes CO_2/capita.
- GDP in national currency or converted to US dollars ($) using purchasing power parities for normalization of total GHG emissions per unit of GDP, unit: tonnes CO_2/$1000.

It is recommended that, in countries where GHG targets exist, these targets be stated in the indicator (although it is recognized that such targets generally apply to all emission sources within a country, and not just the energy-related sectors). These could be expressed either as a percentage reduction in absolute emissions from a base year (as specified by the Kyoto Protocol) or as an intensity target (as for the case of the GHG goal of the USA).

(b) National and International Data Availability and Sources: National communications from Parties to the Convention are available. Developing countries report on a limited basis. At the international level, the UNFCCC Secretariat database has information based on annual data inventory submissions from Annex I Parties to the Convention (see http://ghg.unfccc.int/).

As part of the review process of the UNFCCC, emission levels were initially available only for Annex I Parties to the Convention. Non-Annex I Parties have also started to submit first-hand information on their annual GHG emissions.

The International Energy Agency (IEA) provides data on CO_2 emissions by fuel and sector, and from fossil fuels consumed for electricity, combined heat and power, and district heating. Data are calculated using the IEA's Energy Balance Tables and the Revised 1996 IPCC Guidelines.

The World Bank compiles data on annual anthropogenic emissions of CO_2. These data originate from calculations by the Carbon Dioxide Information Analysis Center (CDIAC), sponsored by the US Department of Energy. The calculations are derived from data on fossil fuel combustion, based on the World Energy Data Set maintained by the UN Statistics Division, and from data on world cement manufacturing, based on the Cement Manufacturing Data Set. To derive data on the quantity of CO_2 emissions from energy use only, the amounts of CO_2 from cement manufacturing have to be subtracted from the World Bank's data on CO_2 emissions.

(c) Data References: The IEA data on CO_2 emissions by fuel and sector, and from electricity and heat generation are reported in the IEA publication *CO_2 Emissions from Fuel Combustion*, published annually. Data on total CO_2 emissions from energy and industrial sources are available from the World Bank report *World Development Indicators*, published annually. Data on CH_4 and N_2O are not available. GHG emissions data for the European Union are available from the European Environment Agency Web site (http://dataservice.eea.eu.int/dataservice/metadetails.asp?id=699).

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ENV2: Ambient concentrations of air pollutants in urban areas

Brief Definition	Ambient concentrations of air pollutants such as ozone, carbon monoxide, particulate matter (PM10, PM2.5, total suspended particulate [TSP], black smoke), sulphur dioxide, nitrogen dioxide, benzene and lead
Units	Micro- or milligrams per cubic metre ($\mu g/m^3$ or mg/m^3), as appropriate
Alternative Definitions	None
Agenda 21	Chapter 9: Protection of the atmosphere

POLICY RELEVANCE

(a) Purpose: This indicator provides a measure of the state of the environment in terms of air quality, which can be a health concern in urban areas. It also provides an indirect measure of the population exposure relevant to impacts on human health and vegetation.

(b) Relevance to Sustainable Development: An increasing percentage of the world's population lives in urban areas. High population density and the concentration of industry and traffic exert great pressures on local environments. Air pollution from energy use in households, industry, power stations and transportation (motor vehicles) is often a major problem. As a result, the greatest potential for human exposure to ambient air pollution and subsequent health problems occurs in urban areas. Improving air quality is a significant aspect of promoting sustainable human settlements. This indicator may be used to monitor trends in air pollution as a basis for prioritizing policy actions; to map levels of air pollution in order to identify hotspots or areas in need of special attention; to help assess the number of people exposed to excessive levels of air pollution; to monitor levels of compliance with air quality standards; to assess the effects of air quality policies; and to help investigate associations between air pollution and health effects.

(c) International Conventions and Agreements: There are several international conventions that focus on controlling air emissions as a means of improving air quality. Concern over emissions of acidifying pollutants has led to several international agreements, including the United Nations Economic Commission for Europe (UNECE) Convention on Long-range Transboundary Air Pollution (CLRTAP) (Geneva, 1979) and its protocols to reduce emissions of sulphur (Helsinki, 1985; Oslo, 1994; Gothenburg, 1999) and nitrogen oxides (Sofia, 1988; Gothenburg, 1999). Two other protocols have also been agreed upon that aim at reducing heavy metals (Aarhus, 1998) and non-methane volatile organic compounds (Geneva, 1991).

(d) International Targets/Recommended Standards: World Health Organization (WHO) air quality guidelines exist for all the pollutants covered by this indicator except nitrogen monoxide. Many countries have established their own air quality standards for many of these pollutants.

(e) Linkages to Other Indicators: This indicator is closely linked to others that relate to energy use and environmental protection, such as annual energy use per capita and per unit of gross domestic product (GDP), air pollutant emissions from energy systems, share of non-carbon fuels and renewables, soil contamination, etc.

METHODOLOGICAL DESCRIPTION

(a) Underlying Definitions and Concepts: This indicator may be designed and constructed in a number of ways. An important aspect that must be considered is the definition of the statistic to be used; for example, where monitoring data are available, the indicator may be expressed in terms of a mean annual concentration, a percentile, or the *n*th highest daily mean, etc., on the basis of either an hourly or daily average.

For health effects, the most appropriate averaging times and statistics are likely to be different for different pollutants. It is therefore recommended that the basis for the indicator be the number of days where concentrations exceed an established threshold (national or international air quality limits) and/or the percentage of the urban population exposed to concentration levels that exceed the target values (e.g. according to European Union legislation, 24-hour average PM10 concentrations above 50 $\mu g/m^3$ are not to be exceeded more than 35 times a year). It should be noted that this type of comparison might need to be made with care because of possible changes or differences in guideline values. However, a simple count of the number of exceedances in a country is an inappropriate final measure for the indicator, as the number of exceedances is likely to increase with increasing numbers of monitoring stations.[1]

Where monitoring data are unavailable, estimates of pollution levels may be made using air pollution models. Dispersion models, however, depend on the availability of emissions data; where these are not available, surveys may be conducted using rapid source inventory techniques. Because of the potential errors in the models or in the input data, results from dispersion models should ideally be validated against monitoring data.

(b) Measuring Methods: Suitable air monitoring networks must fulfil several requirements, such as ensuring representative and comparable measurements, detection limits, interferences, time resolution, ease of operation and cost. There are numerous references on air monitoring and analysis in the literature or available from environmental agencies. The published scientific literature on the subject includes the most appropriate and recent air monitoring methods. Air quality data can be highly dependent on weather conditions, which can give rise to relatively large year-to-year variations. Time-trend data used for the indicator should therefore incorporate as long

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1 Possible ways to avoid this problem include a method developed by the European Environment Agency (EEA) that counts the fraction of available stations recording exceedances and then uses a population-weighted average to calculate urban, national and regional averages. An approach similar to this is recommended (for more information on this methodology, see www.eea.eu.int).

a time frame as possible so that long-term trends can be properly assessed. Measurements for compliance purposes (i.e. the comparison of concentrations with air quality standards) should not just be limited to urban areas, as limit values should not be exceeded anywhere. Concerning exposure and health considerations, urban areas combine a large fraction of the population and elevated concentrations; nevertheless, rural areas should not be excluded from a measuring network. In the case of ozone, for example, rural concentrations can be high downwind of large emission point sources. A number of models are available for estimating ambient concentrations of air pollutants, most of which are based on the Gaussian air dispersion model.

(c) Limitations of the Indicator: Measurement limitations relate to detection limits, interferences, time resolution, ease of operation and cost. Evaluation of the accuracy of model results is critical before model output can be relied on for decision making. To compare the indicator values obtained from different cities, countries should ensure that monitoring networks, monitoring strategies, measuring methods, etc., are compatible.

(d) Alternative Definitions/Indicators: A composite indicator that weighs and sums the main pollutants (e.g. PM10/2.5, nitrous oxides) into one measure could possibly be used, but only if data for all pollutants were regularly available. However, the recommendation of a European Environment Agency (EEA)/WHO workshop in Berlin in 2002 was that this approach should not be used for indicator purposes.

ASSESSMENT OF DATA

(a) Data Needed to Compile the Indicator: Data must include time and spatially representative concentrations, such as mean annual concentrations (mean concentrations of the pollutant of concern, averaged over all hours of the year) or percentile concentration (concentration of the pollutant of concern exceeded in 100 – x% of hours, where x is the percentile as defined by the relevant standards). In addition, information must be available on site location and type (e.g. industrial or residential area).

(b) National and International Data Availability and Sources: Data on ambient air pollution concentrations are often routinely collected by national or local monitoring networks. Universities and research institutes often also collect data for research purposes. In addition, industry collects many data. Data on concentrations of major air pollutants are available for major cities in Organisation for Economic Co-operation and Development (OECD) countries, but more work is needed to improve international comparability and to link these data to national standards and to human health issues.

(c) Data References: Data on ambient air pollution can be obtained from national and local monitoring networks. Sometimes data are available from universities, research institutes and industry. In addition, a growing volume of data can be obtained from international sources such as the WHO Healthy Cities Air Management Information System (AMIS) and the Air Base database of the EEA.

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ENV3: Air pollutant emissions from energy systems

Brief Definition	Emissions of air pollutants from all energy-related activities including electricity production and transportation. Main causes of growing concern are emissions of acidifying substances, such as sulphur oxides (SO_x) and nitrogen oxides (NO_x); ozone-forming gases (ozone precursors), such as volatile organic compounds (VOCs), NO_x and carbon monoxide (CO); and fine particulates
Units	Tonnes or 1000 tonnes
Alternative Definitions	Percentage change in emissions over time; emissions per unit of gross energy use
Auxiliary Data/Indicators	None
Agenda 21	Chapter 9: Protection of the atmosphere

POLICY RELEVANCE

(a) Purpose: This indicator tracks the release of air pollutants into the atmosphere from energy-related activities. It is used to evaluate the environmental performance of national policies and to describe the environmental pressure in relation to air pollution abatement in energy-related activities, including power generation and transportation.

(b) Relevance to Sustainable Development: There is growing concern about higher concentrations of various air pollutants, mainly arising from energy use. The concentration of pollutants is largely influenced by energy production and consumption patterns, which in turn are affected by both energy intensity and efficiency. Emissions of these pollutants are also influenced by national standards of pollution abatement and control, and the use of clean energy technologies. The level of emissions gives an indication of the impact of human activities on the environment. A country's efforts to abate air pollutant emissions are reflected in its national policies and international commitments. Concrete actions include structural changes in energy demand (efficiency improvements and fuel substitution) as well as pollution control policies and technical measures (e.g. the installation of industrial precipitators, denitrification and desulphurisation facilities, and the use of catalytic converters on cars). This indicator can therefore be used to assess environmental pressure in relation to energy production and use, and to evaluate the environmental performance of national policies designed to address four major impacts of air pollutants on health and the environment:

- The acidification of soil and water by pollutants such as SO_x and NO_x.
- The damage to buildings sensitive to these acidifying substances.
- The formation of tropospheric ozone from so-called ozone precursors; for example, VOCs, NO_x and CO, which indirectly affect human and animal health and vegetation.

- The direct effects on human health and ecosystems; for example, through high atmospheric concentrations of particulates and VOCs.

Sulphur and nitrogen compounds are the source of environmental acidification. Anthropogenic nitrogen is predominantly emitted as NO_x by transport sources, as well as by other energy uses and industrial processes. Airborne emissions of NO_x contribute to both local pollution and to large-scale pollution through long-distance transport in the atmosphere.

Air pollutants are associated with respiratory morbidity and mortality in humans; for example, NO_x can irritate the lungs and lower resistance to respiratory infections. The effects of short-term exposure are still unclear, but continued or frequent exposure to concentrations higher than those normally found in the ambient air may cause increased incidence of acute respiratory disease.

In the presence of sunlight, NO_x react with VOCs to form tropospheric ozone and other oxidizing chemicals, which are toxic to living things, including human beings. NO_x and sulphur dioxide (SO_2) are also precursors to acids in rainwater and subsequently have deleterious effects on artefacts, aquatic organisms, agriculture and habitats. Atmospheric deposition of NO_x can also contribute to eutrophication. In some areas, NO_x are precursors to particulate matter concentrations. The deposition of nitrogen may be dry (in the form of gases and particles) or wet (in the form of rain or snow), or in the form of condensation (as fog and cloud droplets).

(c) International Conventions and Agreements: Concern over emissions of acidifying pollutants has led to several international agreements, including the United Nations Economic Commission for Europe (UNECE) Convention on Long-range Transboundary Air Pollution (CLRTAP) (Geneva, 1979) and its protocols to reduce emissions of sulphur (Helsinki, 1985; Oslo, 1994; Gothenburg, 1999) and NO_x (Sofia, 1988; Gothenburg, 1999). Two other protocols have also been agreed upon that aim at reducing heavy metals (Aarhus, 1998) and non-methane volatile organic compounds, or NMVOCs (Geneva, 1991).

(d) International Targets/Recommended Standards: The 1999 Gothenburg Protocol to Abate Acidification, Eutrophication and Ground-level Ozone sets emission ceiling targets for SO_2, NO_x, NMVOCs and ammonia (NH_3) for UNECE countries. European Union Member States are also required to meet National Emission Ceiling Directive (NECD) targets for 2010. Some countries have set national targets that are stricter than those of the international agreements, but few have yet met these national targets.

(e) Linkages to Other Indicators: In addition to annual air pollutant emissions and their percentage changes, emission intensities (expressed as quantities of pollutant emitted per unit of gross energy used) should be presented in order to assess sustainability. This set of indicators is therefore closely linked to issues such as fuel mix, annual energy use per capita and transport fuel consumption, in addition to the status of abatement technology and expenditure on air pollution abatement within individual countries.

METHODOLOGICAL DESCRIPTION

(a) Underlying Definitions and Concepts: Air pollution stems from gases and airborne particles that, in excess, are harmful to human health, artefacts and ecosystems. Emissions of air pollutants from anthropogenic activities are often directly related to the combustion of fossil fuels for energy. However, non-energy-related emission sources are also significant for some pollutants — for example, NMVOCs. Emissions of greenhouse gases, or GHGs (e.g. carbon dioxide [CO_2], nitrous oxide [N_2O] and methane [CH_4]), are excluded from the scope of this indicator and are described separately in the GHG emissions indicator.

Sulphur Dioxide (SO_2): The primary product from the combustion of sulphur is SO_2. However, other sulphur oxide compounds can also be produced; thus, when reported, these compounds are to be jointly referred to as SO_x (sulphur oxides).

Nitrogen Oxides (NO_x): The primary combustion product of nitrogen is nitrogen dioxide (NO_2). However, several other nitrogen compounds are usually emitted at the same time, such as nitrogen monoxide (NO), nitrous oxide (N_2O), etc., and these may or may not be distinguishable in available test data. Total NO_x is to be reported on the basis of the molecular weight of NO_2.

Volatile Organic Compounds (VOCs): VOCs are defined as any compound of carbon (excluding CO, CO_2, carbonic acid, metallic carbides or carbonates, and ammonium carbonate) that participates in atmospheric chemical reactions. In some cases, the term non-methane volatile organic compound (NMVOC) is used to indicate that methane is exempt from the VOC categorization.

Carbon Monoxide (CO): CO is formed from the incomplete combustion of fossil fuels. In most countries the transport sector is the main source of CO emissions.

Emissions of NO_x, VOCs, CO and CH_4 contribute to the formation of ground-level (or tropospheric) ozone. These ozone precursors can be aggregated on the basis of their ozone-forming potential to assess the combined impact of the different pollutants. The relative weighting factors are as follows: NO_x, 1.22; NMVOCs, 1.0; CO, 0.11; and CH_4, 0.014. This methodology is routinely used by the European Environment Agency (EEA) for its reporting of ozone formation, but the use of such factors does not yet have broad international acceptance. The factors are assumed to be representative for Europe as a whole, but on the local geographical scale, the factors may vary (for further information regarding uncertainties in these factors, see De Leeuw 2002).

Particulates: Terms commonly associated with particulate matter are particulate matter with a diameter less than 10 μm (PM10), total suspended particulate (TSP), primary particulate and secondary particulate. PM10 in the atmosphere can result from direct particulate emissions (primary PM10) or from emissions of gaseous particulate precursors that are partly transformed into particles by chemical reactions in the atmosphere (secondary PM10). TSP consists of matter emitted from sources in solid, liquid and vapour forms, but existing in the ambient air as particulate solids or liquids.

Secondary PM10 precursors include SO_2, NO_x, NH_3 and VOCs. Reliable information on the relative contribution of VOCs to particulate formation is not available. For estimations of quantities of secondary particulates, aerosol formation factors could be used to assess the aggregated particulate formation potential arising from emissions of the different secondary pollutants (see De Leeuw 2002). The factors are as follows: SO_2, 0.54; NO_x, 0.88; and NH_3, 0.64. It should be noted that, as for the tropospheric ozone formation factors, these factors are only a best approximation of the relative contribution of the different pollutants and significant local variations may actually occur in both urban and rural areas.

Since the objective of this set of indicators is to describe the impact of human activities on the environment, emissions from natural sources (such as forest fires and volcanic eruptions) should be excluded from the indicator.

The indicator should therefore present annual air pollutant emissions and their percentage changes. Emission intensity expressed as quantities of pollutant emitted per unit of gross energy use could be used to assess sustainability. It would also be useful if policy-relevant information on emission targets were included in the indicator (if such targets exist for a given country). This would allow an assessment of the ‘distance to target’ for a country, and hence whether existing pollution abatement measures are sufficient to meet existing national or international targets.

(b) Measuring Methods: In some cases emissions from, for example, industrial plants can be estimated based on actual direct measurements in stacks or by material balances. However, in general, pollutant emissions are calculated with the help of an emission factor, which is a representative value that attempts to relate the quantity of a pollutant released to the atmosphere with an activity associated with the release of that pollutant. These factors are usually expressed as the weight of the pollutant divided by a unit weight, volume, distance or duration of the activity emitting the pollutant (e.g. kilograms of particulate emitted per tonne of coal burned). Such factors facilitate the estimation of emissions from various sources of air pollution and ideally are known on a facility- or country-specific basis. In most cases, these factors are simply averages of all available data of acceptable quality and are generally assumed to be representative of long-term averages for all facilities in the source category (i.e. a population average).

Work to standardize sampling and analytical methods for air pollution has been completed by the International Organization for Standardization, the World Meteorological Organization (WMO), the World Health Organization (WHO), the UNECE, the Organisation for Economic Co-operation and Development (OECD) and the Co-operative Programme for Monitoring and Evaluation of the Long-Range Transmission of Air Pollutants in Europe (EMEP).

Similarly, in recent years, considerable effort has been made to standardize or harmonize the calculation of national emission inventories for air pollutants in order to improve the comparability of national estimates. There have been a number of initiatives that provide guidance to countries on the creation, compilation and reporting of pollutant release inventories. These include the EMEP/Corinair Guidebook (EMEP/EEA, 2004), the OECD Pollutant Release and Transfer Register (PRTR) programme guidance (OECD, 1996), and the United Nations Institute for Training and Research (UNITAR) guidance on pollutant release and transfer registers (UNITAR, 1997). The last of these is specifically designed to support and facilitate the national PRTR design process within developing and industrializing countries.

In the first instance, countries should consult existing information sources to obtain specific guidance on, for example, energy sector definitions and the recommended emission estimation or measurement methodologies. Regarding the reporting of inventories, estimations of data from previous years are typically subject to revision as estimation methods become better and countries shift from using default emission factors to country-specific factors.

To assess sustainability, ideally it would be possible to study the trends in emissions over long time periods (e.g. 20 or 30 years). However, even within Europe, where air pollutant emissions have been reported for a number of years, reported emissions for years before 1990 are generally not complete and may also be unreliable due to the non-availability of historical activity data, technology-specific emission factors, etc. Time series reporting should therefore initially focus on accurate reporting from 1990, the baseline reporting year for many international agreements.

(c) Limitations of the Indicator: (i) This indicator quantifies air pollution resulting from energy use only; thus it ignores pollutant emissions related to other activities, such as those of the industrial and agricultural sectors. In general, these sectors are not dominant sources for the pollutants discussed, but to some extent they do contribute to total exposures. (ii) The indicator assumes that countries have adequate national statistical services to enable an air pollutant release and transfer register/inventory to be established. (iii) When interpreting this indicator, it should be read in connection with the indicator for urban air quality. (iv) The level of detail required for various combustion processes, particularly data related to machinery characteristics, might not be readily available for certain activities. In this case, default emission factors from existing sources of inventory compilation guidance should be used to obtain estimates of the pollutant emissions released into the atmosphere.

(d) Alternative Definitions/Indicators: Alternatively, the percentage change in emissions over time (e.g. the percentage change in emissions between 1990 and the most recent year) may be considered; that is, indexed emissions relative to a 1990 baseline. Normalized forms of indicators are useful for cross-country comparisons (i.e. emissions per unit of gross energy use).

ASSESSMENT OF DATA

(a) Data Needed to Compile the Indicator: Quantities of emissions of air pollutants from all energy-related activities, particularly from the electricity production and transportation sectors. Proposed denominator for a normalized indicator: Unit of gross energy use.

(b) National and International Data Availability and Sources: Most European countries report emissions of air pollutants annually under the protocols of the CLRTAP. Globally however, the main challenge concerning data is to increase the frequency with which the data are collected, processed and updated at the national level. Annual changes in emissions cannot be calculated unless annual data are available. In a number of countries, the current practice still is to publish emission inventories at five-year intervals. Additional efforts are needed to improve the availability, completeness and comparability of data for air pollutant emissions.

(c) Data References: The EMEP Web site contains a database (http://www.emep.int/index_data.html) that has been developed to support the CLRTAP protocols. It includes emissions data for around 50 (mostly European) countries. Trends in emissions of ozone precursors in Europe can be found on the EEA Web site (http://dataservice.eea.eu.int/dataservice/metadetails.asp?id=700). Related work is being carried out by EMEP, the United Nations Environment Programme (UNEP), UNECE, The World Bank, the UN Commission on Sustainable Development (CSD), Eurostat and the EEA.

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ENV4-1: Contaminant discharges in liquid effluents from energy systems

Brief Definition	Contaminant discharges in liquid effluents from all energy-related activities, including the discharge of cooling waters, which can raise the temperature of the watercourse
Units	Kilograms (kg) or milligrams (mg) per litre
Alternative Definitions	Mass emission or concentration in the discharge
Agenda 21	Chapter 17: Protection of the oceans, all kinds of seas, including enclosed and semi-enclosed seas, and coastal areas and the protection, rational use and development of their living resources Chapter 18: Protection of the quality and supply of freshwater resources: application of integrated approaches to the development, management and use of water resources

POLICY RELEVANCE

(a) Purpose: The purpose of this indicator is to monitor the discharge of harmful pollutants from energy industries, particularly coal mining and oil extraction, into rivers, lakes and marine waters.

(b) Relevance to Sustainable Development: Fresh water is a scarce resource in many parts of the world and needs to be used wisely to ensure and maintain sustainable quantities of good-quality supplies. Fresh water is used as a source for potable supply, arable crop irrigation and drinking water for farm animals and is the habitat for plants, fish species and other wildlife. Polluted water can have a direct impact on human health and on the ability of livestock and crops to thrive, resulting in sickly livestock, lower yields and, depending on the pollutant, contaminated farm produce.

The marine environment is also an important habitat for aquatic life and an important resource for fishing, aquaculture, tourism and recreation.

Freshwater and marine environments are often fragile habitats, and avoiding the destruction of these habitats is a priority for ensuring a sustainable future.

(c) International Conventions and Agreements: The importance of ensuring the protection of marine and fresh waters has been recognized by the Convention on Biological Diversity (CBD) and the United Nations Convention on the Law of the Sea (UNCLOS), which advocates an integrated, ecosystem approach to protect the oceans and coastal areas. Other conventions include the non-binding Global Programme of Action for the Protection of the Marine Environment from Land-based Activities (GPA); the Washington Declaration (1995) implemented by the United Nations Environment Programme (UNEP); and the Paris Convention (1974). The Convention on the Law of the Non-navigational Uses of International Watercourses provides measures to protect, preserve and manage these watercourses. It addresses such issues as flood control, water quality, erosion, sedimentation, saltwater intrusion and living resources. The United Nations Economic Commission for Europe (UNECE) Convention on the Protection and Use of Transboundary Watercourses and International Lakes (1992) includes national and international measures to prevent, control and reduce the release of hazardous substances into the aquatic environment. It also includes measures to abate eutrophication and acidification, as well for the prevention, control and reduction of transboundary pollution. The goal is to encourage sustainable water management, conservation of water resources and environmental protection.

(d) International Targets/Recommended Standards: The World Health Organization (WHO) has established some water law standards.

(e) Linkages to Other Indicators: This indicator is linked to indicators of energy production and electricity generation and to other environmental indicators such as discharges of oil into coastal waters, greenhouse gas emissions, air pollutant emissions, etc.

METHODOLOGICAL DESCRIPTION

(a) Underlying Definitions and Concepts: Water pollution from energy industries depends very much on the activity and the type of technology and abatement techniques used. Most important in this respect are the coal mining and oil extraction industries, but the use of energy in industry in general can lead to discharges of pollutants into water bodies. A range of by-products and residues are generated in energy production, including bottom ash, fluidised bed ash, fly ash and flue gas desulphurisation residues and by-products. Knowledge of the process and the pollutants likely to be generated is necessary when developing a programme for monitoring water quality.

When measuring water quality, measurements can be made directly in effluent discharges or in the downstream watercourse as a measure of the environmental impact of the discharge. The following list presents typical monitoring requirements for energy industries:

Flow Rate: Volume, measured in cubic metres per second, hour or day. Volumes can be multiplied by the concentration of the pollutant to calculate the mass emissions of individual pollutants.

pH: This is a measure of the acidity/alkalinity of a discharge. The pH of a watercourse affects the solubility of various substances and alters the habitat for fish, animals and plants.

Total Organic Carbon (TOC): Measured in milligrams per litre (this can be used as a surrogate for chemical oxygen demand [COD] or biochemical oxygen demand [BOD]). TOC measures the organic content in a discharge, which can sometimes be elevated when the discharge is contaminated. Elevated levels of organic matter change the natural balance of plants and organisms in the watercourse.

Hydrocarbon Oil: Measured in milligrams per litre. Surface water drainage passing through industrial facilities and storage areas can often become contaminated with hydrocarbon oil, which can pollute watercourses and harm plants and animals downstream. Contamination of fresh water with very low levels of oils makes the water undrinkable (see ENV4-2: Oil discharges into coastal waters).

Suspended Solids: Measured in milligrams per litre. These can often contaminate watercourses downstream of storage areas or from mining/drilling operations. Suspended solids colour the water, change the opacity of the water and can smother plants and animals downstream.

Ammoniacal and Total Nitrogen: Measured in milligrams per litre. Nitrogen is a nutrient, which often causes nutriphication of the watercourse, changing the habitat and affecting native species.

Chloride and Sulphides: Measured in milligrams per litre. Wastewater from flue gas desulphurisation plants contains salts such as chloride and sulphides, which can be particularly damaging when released into freshwater environments.

Phenols and Sulphides: Measured in milligrams per litre. These are by-products of gasification and carbonization processes and can also be present in drainage water from coal stockyards, etc.

Metals (typically cadmium [Cd], mercury [Hg], chromium [Cr], nickel [Ni], vanadium [V], zinc [Zn], copper [Cu], arsenic [As] and boron [B]): Measured in milligrams per litre. Metals can leach out of fuel stockpiles and are often released from the various ashes and wastes that arise from energy industries.

(b) Measuring Methods: Measurement methods for water discharges are straightforward and well established and should conform to widely adopted international standards, such as the International Organization for Standardization (ISO) standards.

(c) Limitations of the Indicator: (i) When the quality of the water body itself is monitored, it is not always possible to distinguish between pollution resulting from energy activities and pollution from other activities, such as those in the industrial and agricultural sectors. For this reason, it is preferable to monitor direct discharges from the activity as they enter the water body. (ii) It is difficult, and perhaps not helpful, to aggregate into a single indicator the measurements for all pollutants taken at different times and points along the watercourse. Therefore, this indicator is in fact a number of different indicators, depending on the number of pollutants being measured.

(d) Alternative Definitions/Indicators: An alternative indicator is annual water pollutant discharges (as a mass emission – concentration *x* flow) and their percentage changes. It would also be useful if policy-relevant information on emission targets were to be included in the indicator (if such targets exist for a given country). This allows an assessment of the 'distance to target' for a country, and hence whether existing pollution abatement measures are sufficient to meet existing national or international targets.

Alternatively, the percentage change in discharges over time (e.g. the percentage change in discharges between 1990 and 2000) may be considered; that is, indexed emissions relative to a 1990 baseline.

ASSESSMENT OF DATA

(a) Data Needed to Compile the Indicator: Either (i) quantities of pollutants discharged from all energy-related activities, particularly from coal mining and oil extraction, or (ii) monthly or annual average site-specific concentrations of each of the pollutants.

(b) National and International Data Availability and Sources: In Europe, information on discharges from energy industries can be found in the European Pollutant Emission Register (EPER), which was established by the European Commission as an inventory of emissions from those industries covered by Council Directive 96/61/EC concerning integrated pollution prevention and control (which includes large energy producers). Globally, however, the main challenge concerning data is to increase the frequency with which the data are collected, processed and updated at the national level. In a number of countries, the current practice still is to publish emission inventories at five-year intervals. Additional efforts are needed to improve the availability, completeness and comparability of data for air pollutant emissions.

(c) Data References: Emissions data are available from the European Pollutant Emissions Register (http://www.eper.cec.eu.int). The European Environment Agency (EEA) provides information on water data flows and assessments (http://themes.eea.eu.int/Specific_media/water). The WHO maintains a Web site with information on water-law standards (http://www.who.int/waterlaw/).

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ENV4-2: Oil discharges into coastal waters

Brief Definition	Total accidental, licensed and illegal disposal of mineral oil into the coastal and marine environment
Units	Tonnes
Alternative Definitions	None
Agenda 21	Chapter 17: Protection of the oceans, all kinds of seas, including enclosed and semi-enclosed seas, and coastal areas and the protection, rational use and development of their living resources

POLICY RELEVANCE

(a) Purpose: This indicator shows the amount of oil discharged into coastal waters and the effectiveness of measures designed to reduce these discharges over time in accordance with regional seas conventions and action plans.

(b) Relevance to Sustainable Development: Coastal ecosystems provide important economic benefits, such as fisheries, tourism and outdoor recreation. They are also important for biodiversity, which is recognized by the Convention on Biological Diversity (CBD). Agenda 21, based on the United Nations Convention on the Law of the Sea (UNCLOS), advocates an integrated, ecosystem approach to protect oceans and coastal areas. Such an approach is heavily dependent on the application of precautionary and anticipatory principles to maintain biodiversity and ecosystem productivity while improving the quality of life of coastal communities.

Oil lost or discharged into the sea represents a pollution threat that can damage coastal ecosystems, endanger marine life and pollute beaches and coastlines. Its toxic effects can kill or damage marine organisms, and its physical effects on marine life can result in the loss of water-repellent properties and reduced thermal insulation and buoyancy. Furthermore, oil spills can have a considerable impact on human activities that depend on clean seawater and clean shores, notably tourism, fishing and aquaculture.

Oil is used by the population at large and enters the marine and coastal environment not only directly from shipping, oil drilling, etc., but also as the final sink from a large variety of hinterland uses. Although there may be legislation to limit this ‘background’ pollution, enforcement depends heavily on the public’s understanding of the threat, good practices and the reward of good practices. By focusing on the input from all sources and designing suitable monitoring and reporting techniques, an indicator can be developed that could be used for assessing policies and defining strategies for improving the situation.

The impact of oil pollution depends on the type of oil and the sensitivity of the specific area affected, as well as the weather and the way the cleanup is handled. Damage to a salt marsh polluted by oil may be almost irreversible, whereas a rocky shore can be restored with a relatively quick and satisfactory recovery programme.

(c) International Conventions and Agreements: This indicator is relevant to the UNCLOS (1982), the non-binding Global Programme of Action for the Protection of the Marine Environment from Land-based Activities (GPA) and the Washington Declaration (1995) implemented by the United Nations Environment Programme (UNEP).

The Paris Convention seeks to prevent and eliminate pollution and to protect maritime areas against the adverse effects of human activities.

In addition, each of the regional seas has its own convention or action plan; in particular, the Helsinki Convention (HELCOM) refers to protection of the Baltic and the Kattegat Seas.

(d) International Targets/Recommended Standards: Some regional targets exist.

(e) Linkages to Other Indicators: This indicator is linked to indicators for oil and gas production, consumption and import. It is also linked to other environmental indicators related to contaminant discharges in water, greenhouse gas emissions, air pollutant emissions, etc.

METHODOLOGICAL DESCRIPTION

(a) Underlying Definitions and Concepts: Oil pollution in coastal waters essentially takes place in two ways, either as large discharges during a short period owing to accidents (acute discharges) or as small but continual discharges over a longer period (chronic or diffuse discharges). It is estimated that 1% of the total amount of oil transported by sea is discharged.

There are multiple sources of oil pollution in coastal areas and marine environments. The major sources include the following:

- Discharges from coastal industries; for example, petrochemical and oil refineries, and factories using oil-based products as feedstock.
- Discharges from coastal iron, steel and non-ferrous industries, as well as from engineering and surface treatment industries that use oil in various processes and operations.
- Discharges and overflows of storm water, which often contain oil, soot, grease, etc.
- Discharges of diffuse inputs from various sources.
- Shipping accidents at sea that release oil.
- Accidents in connection with oil and gas production, such as blowouts, explosions and fires.
- Discharges from ships in operation, including legal as well as illegal discharges (e.g. tank cleaning at sea, which is prohibited).
- Recurrent discharges entering the sea around oil platforms from drilling muds and oil production water.
- Spills during the loading or unloading of crude oil and petroleum products, refuelling and other port operations.
- Atmospheric deposition.

(b) Measuring Methods: Estimates of oil discharges from various sources on land and at sea are normally made indirectly. For ship accidents, the amount of oil lost is estimated as the difference between the amount carried and the amount retained after the accident. For oil fingerprinted as bilge water, the expected bilge load, known from ships that discharge their waste oil legally, is also estimated. Only in a few cases has the amount of oil discharged into the marine environment been monitored on a regular basis (e.g. discharge of oil from refineries). For some regions, aerial surveillance is available.

(c) Limitations of the Indicator: Accidental or routine discharges are, in many cases, not accounted for. In general, available data sets are very limited, as oil is discharged from many different sources. In many countries, oil discharges are not included in national environmental monitoring programmes. It therefore is not possible at present to develop realistic estimates showing actual input and time series to illustrate real trends.

(d) Alternative Definitions/Indicators: Because of current limitations on discharge data, an alternative definition could be based on the amount of oil input to marine and coastal environments by the major sources, namely the oil lost by offshore activities, the oil discharged by coastal refineries and spills from shipping. Such an approach excludes input from riverine and atmospheric deposition.

The indicator can be disaggregated into two sub-indicators: (i) oil discharges from land-based and offshore installations and (ii) accidental oil discharges, legal oil spills and illegal spills from ships at sea.

ASSESSMENT OF DATA

(a) Data Needed to Compile the Indicator: Estimates of oil input to coastal areas and seas from the main sources of oil disposal.

(b) National and International Data Availability: Two particularly important international data sources are the following:

CONCAWE (CONservation of Clean Air and Water in Europe): The oil companies' European association for environment, health and safety in refining and distribution, CONCAWE issues reports on a regular basis on West European oil refinery effluents, including water quality, oil content and quantities.

ITOPF (International Tanker Owners Pollution Federation Limited): Since 1974, ITOPF has maintained a database on oil spills from tankers, combined carriers and barges.

International sea commissions are also sources of data and contribute information about aerial surveillance activities, estimates of direct oil discharges from specific point sources, etc.

(c) Data References: Data at the regional level are available from the Regional Seas Programme of the UNEP (http://www.unep.ch/seas/rshome.html).

Data at the international level may be available from the United Nations Environmental Assessment sub-programme (http://www.unep.org).

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ENV5: Soil area where acidification exceeds critical load

Brief Definition	Soil area where damage could occur due to acidification levels that exceed critical loads
Units	Square kilometres (km^2)
Alternative Definitions	Soil areas exceeding specific target loads
Agenda 21	Chapter 9: Protection of the atmosphere

POLICY RELEVANCE

(a) Purpose: This indicator describes the extent of acidification at the national level. It is used to monitor the state and trends in the severity of acidification caused by wet and dry deposition over time, and to evaluate the environmental performance of national air pollution abatement policies. The indicator should show acidification attributable to all sources and, where appropriate national data are available, acidification due to emissions from the energy sector alone.

(b) Relevance to Sustainable Development: When both sulphur and nitrogen compounds settle out of the atmosphere in the form of wet deposition (acid rain) or dry deposition, the resulting acidification of soils and surface waters can have serious consequences for both plant life and water fauna. When the soil becomes acidified, its essential nutrients are leached out, which reduces the fertility of the soil. The acidification process also releases metals that can harm the microorganisms in the soil that are responsible for decomposition, as well as birds and mammals higher up in the food chain, including humans. The acidifying effects of acid deposition and land use must not exceed the limits that can be tolerated by the area in question.

Acidification is a priority atmospheric issue considered by Agenda 21 in addressing degradation of soil and surface-water resources. Therefore, there should be a mechanism for determining the importance of this issue at the national level. Trend data over time can indicate the success of response actions. Concrete actions include structural changes in energy demand (efficiency improvements and fuel substitution) as well as pollution control policies and technical measures.

(c) International Conventions and Agreements: The following agreements are relevant to this indicator: the United Nations Economic Commission for Europe (UNECE) Convention on Long-range Transboundary Air Pollution (CLRTAP) (Geneva, 1979) and its protocols to reduce emissions of sulphur (Helsinki, 1985, Oslo, 1994, Gothenburg, 1999) and nitrogen oxides (Sofia, 1988, Gothenburg, 1999). These protocols are widely accepted as a major step in combating environmental acidification in Europe. A new multi-pollutant, multi-effect protocol on acidification, eutrophication and ground-level ozone was signed by the European Union (EU) Member States in Gothenburg in 1999. Exceedance of critical loads is also covered by the Acidification Strategy of the EU.

(d) International Targets/Recommended Standards: No specific targets have been defined; however, the goal worldwide should be to reduce the area of soil affected by acidification and/or to reduce the severity of acidification. In the EU in the long term, the target is to cut acidifying emissions to levels whereby critical loads will not be exceeded anywhere.

(e) Linkages to Other Indicators: The indicator is linked to other environmental indicators such as air pollutant emissions from energy systems, which includes emissions of sulphur oxides (SO_x) and nitrogen oxides (NO_x).

METHODOLOGICAL DESCRIPTION

(a) Underlying Definitions and Concepts: The environment's ability to withstand acid precipitation is measured by the concept of a critical load, which is now accepted as a basis for political decisions on reductions of emissions of sulphur and nitrogen. A critical load represents a quantitative estimate of a long-term exposure to acid pollutants that the environment (ecosystem), according to present knowledge, can absorb without sustaining damage or, in other words, the pollution load that the environment can withstand. The area where critical loads are exceeded provides an indication of the ecosystem area in which damage could occur. Exceedance of critical loads is a complex function of the deposition of various pollutants and the natural buffering ability of the waterway or soil in question. Long-range transboundary air pollution plays a significant role in areas where the critical load is exceeded. The number of exceedances of critical loads has therefore come to be adopted as a proxy measure for the level of ecosystem protection.

It is important to distinguish between the concepts of ecosystem protection and the concept of exceedance of critical loads. Targets for reducing acidification are mainly aimed at addressing the gap between the present level of exceedances and a 'zero' level of exceedances; that is, the gap closure approach. Both the EU Acidification Strategy and the UNECE protocols use the gap closure approach; both have the long-term goal of reducing the number of unprotected ecosystems to zero. The main difference between the two is in the planned pace of attainment, with the EU targets being required to be reached on a faster time scale.

(b) Measuring Methods: The area of soil where critical loads are exceeded determined by the sum of all ecosystem areas in grid cells where exceedances occur. Levels of acidification that exceed critical loads are calculated by considering both sulphur and nitrogen deposition. The data are directly derived from official national sources.

(c) Limitations of the Indicator: The values of the exceedance of critical loads are highly dependent on the size of the grid cells used for the calculations. In particular, the area of a protected ecosystem can vary considerably depending on the spatial resolution of the grid system. This means that the accuracy of the method depends on the grid size (currently 50x50 km for deposition modelling). More research is needed to increase the robustness of the calculations.

In many cases the critical loads are determined only for the acidity of sulphur. The total acidity of sulphur and nitrogen needs to be determined so that a coherent agreement can be reached regarding abatement policies. Numerous methods are available for obtaining critical loads. To obtain values for the critical loads, an ecosystem has to be chosen and then a suitable indicator species must be selected to represent the ecosystem. A chemical limit is subsequently defined as the concentration at which the indicator species will die. In forests the indicators are trees, and in fresh waters they are fish.

(d) Alternative Definitions/Indicators: The concept behind critical loads is based on a dose-response relationship where the threshold of harmful response (within the ecosystem) is triggered by a certain load of pollutant — the critical load. However, it is not always easy to apply the concept without careful consideration of the nature of the affected ecosystem and the threshold effects of harmful pollutants. For critical loads to be used, 'target loads' can be set for different areas in order to try to halt the acidification processes. Target loads have been defined as 'the permitted pollutant load determined by political agreement'. Therefore, target loads can be either higher or lower than the scientifically determined critical load values. For example, the target load may be lower so as to give a safety margin, or the target load may be higher for economic reasons. There are also increasing possibilities for mapping critical loads for individual ecosystems (e.g. there has been much recent attention given to the application of acidification modelling to forest ecosystems).

ASSESSMENT OF DATA

(a) Data Needed to Compile the Indicator: Critical load values for total acidity of sulphur and nitrogen, combined with acid deposition values, in order that exceedance values can be produced showing the area of soil where critical loads are being exceeded. Countries should make clear the data validation processes for the emissions, deposition and critical load determinations that are used as the basis for the development of the indicator.

(b) National and International Data Availability: Critical loads are calculated by the countries of the CLRTAP and are collected and mapped over Europe by the Coordination Center for Effects (CCE). Every year, emissions data are reported by national authorities under the CLRTAP. The emissions data include both new estimates of emissions for two years in areas and updated information on emissions from previous years. The emissions data are stored and verified in the European Monitoring and Evaluation Programme's Meteorological Synthesizing Centre — West (EMEP/MSC-W). On the basis of these emissions, EMEP/MSC-W carries out calculations of atmospheric transport of sulphur and nitrogen pollutants according to recorded meteorological conditions. Updated deposition calculations are used as a basis for the calculation of exceedances of critical loads at the CCE. Results are presented in the yearly update of the EMEP report on Transboundary Acidification and Eutrophication in Europe.

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<u>ENV6:</u> Rate of deforestation attributed to energy use

Brief Definition	Annual change in the amount of natural and plantation forest area tracked over time that could be attributed to using wood as a fuel for energy purposes
Units	Percentage
Alternative Definitions	Ratio of fuelwood deforestation rate to total deforestation rate
Agenda 21	Chapter 11: Combating deforestation

POLICY RELEVANCE

(a) Purpose: The purpose of this indicator is to show a change in the area covered by the forest formations of a country over time that could be attributed to using wood for energy needs.

(b) Relevance to Sustainable Development: Forests serve multiple ecological, socio-economic and cultural roles in many countries. They are among the most diverse and widespread ecosystems of the world. Forests provide many significant resources, including wood products, recreational opportunities and habitat for wildlife, and serve many important functions, such as filtering pollutants and playing a role in water and soil conservation. They support employment and traditional uses, as well as biodiversity. There is general concern about the human impact on forest health and the natural processes of forest growth and regeneration. It is estimated that, between 1980 and 1990, the global forest area declined by 180 million hectares (ha), with a further decline of 56 million ha from 1990 to 1995. Combating deforestation to maintain the production of fuelwood and other non-fuel wood and to preserve soils, water, air and biological diversity is explicitly considered in Agenda 21. Deforestation, in particular due to fuelwood harvest, is seen as a major issue in developing countries. The issue is of less concern in developed countries, where the area volume of fuelwood consumption is negligible.

The availability of accurate data on a country's forest area, which is a basic indication of its forest resources, is an essential requirement for forest policymaking and planning within the context of sustainable development.

(c) International Conventions and Agreements: Many international agreements exist encouraging countries to maintain or increase their forested areas. Specific forest agreements include the Non-Legally Binding Authoritative Statement of Principles for a Global Consensus on the Management, Conservation and Sustainable Development of All Types of Forests (the Forest Principles of the United Nations Conference on Environment and Development [UNCED]) and the International Tropical Timber Agreement. Many other international agreements deal with forests within the context of natural resources and environment conservation; for example, the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), the Convention on the Conservation of Wetlands of International Importance Especially as Waterfowl Habitat (Ramsar Convention), the Convention on Biological Diversity, the United Nations Framework Convention on Climate Change (UNFCCC) and the

United Nations Convention to Combat Desertification (UNCCD). In addition, several regional conventions cover forests.

(d) International Targets/Recommended Standards: There are no international targets or standards set for size of forest or rate of deforestation. It is understood, however, that the higher the deforestation rate, the more critical the environmental impact might be in a country or region. Several countries have set targets for the extent of their forest area, either in absolute values or as a percentage of the total land area of the country.

(e) Linkages to Other Indicators: This indicator is linked to several social and economic indicators, such as consumption of combustible renewables and waste (CRW) per capita; share of CRW in energy mix, and in particular share of fuelwood in CRW; and share of households or population without electricity or commercial energy, or heavily dependent on non-commercial energy.

METHODOLOGICAL DESCRIPTION

(a) Underlying Definitions and Concepts: Definitions are available from the Forest Resources Assessments of the Food and Agricultural Organization of the United Nations (FAO). *Forest area* is defined as lands with a tree crown cover equal to or more than 10% of the area; *plantation* as the artificial establishment of forests by planting or seeding; and *natural forests* as natural and/or semi-natural established forests. The comparisons of forest area over time using reference years allows the calculation of change in absolute values and as a percentage of the total rate of deforestation (*TRD*). The rate of deforestation attributed to the use of wood as fuel (RD_{fw}) is determined by using the ratio of the average annual fuelwood production (*FWP*) to the annual total forest fellings (*TFF*).

(b) Measuring Methods: The measurement methods for forest area can be contained in national forest inventories and obtained by remote sensing, by sampling ground or cadastral surveys, or through a combination of these methods.

The forest area is calculated as the sum of plantations and natural forest areas with tree crown cover of at least 10%. This calculation is made at given reference years as follows:

The total rate of deforestation (*TRD*) is the compound annual rate in percent from year *P* to year *N*:

$$TRD = 100\left(1 - \left(\frac{Forest\ area_N}{Forest\ area_P}\right)^{\left(\frac{1}{(N-P)}\right)}\right) .$$

Then, the rate of deforestation attributed to fuelwood (RD_{fw}) is

$$RD_{fw} = TRD\left(\frac{FWP}{TFF}\right) ,$$

where *FWP* is annual fuelwood production and *TFF* is annual total forest fellings.

(c) Limitations of the Indicator: The indicator does not measure the total rate of deforestation but focuses only on deforestation caused by harvesting of fuelwood. The area value does not give any indication of the quality of the forest or of forest values or practices. The indicator does not provide information on the degradation of the forest resources in a country. The total forest area in a country might remain unchanged, even as the quality of the forest degrades. The indicator covers an extremely diverse range of forests, from open tree savannah to dense tropical forests.

(d) Alternative Definitions/Indicators: The ratio of rate of deforestation related to fuelwood harvest to the total rate of deforestation could serve as an alternative indicator to measure the impact of use of forest resources as fuelwood on deforestation.

ASSESSMENT OF DATA

(a) Data Needed to Compile the Indicator: The total forest area of a country, including plantations, at different yearly intervals; fuelwood production or use; and the annual total forest fellings. Data on the fuelwood harvest might be available from national agencies responsible for forestry. If there is no reliable information on the level of fuelwood production, the data on CRW compiled by the International Energy Agency (IEA) for many developing and developed countries could be used as a proxy.

(b) National and International Data Availability: Data on the extent of forests (natural and plantations) and total forest fellings are available for most countries, at both the national and sub-national scales. The data are often estimates, which are not always comparable because of changes in definitions and assessment methodologies. International data are available from FAO Forest Resources Assessments and the statistics of the United Nations Economic Commission for Europe (UNECE). National data are available from ministries responsible for forestry and statistics. International data provided by other institutions — for example, the World Resources Institute — are mostly based on information from the FAO Forest Resources Assessments.

(c) Data References: The primary international sources of data are the FAO and the UNECE, which collect data on forest area and fellings on a regular 10-year basis. Data on harvested fuelwood are available from national ministries responsible for forestry. CRW data for many countries are available in the IEA statistics.

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ENV7: Ratio of solid waste generation to units of energy produced

Brief Definition	Amount of solid waste (excluding radioactive waste) produced annually from activities related to the extraction and conditioning of primary fuels, and waste produced in thermal power plants, expressed as weight of waste per unit of energy produced
Units	Tonnes of waste per unit of energy produced (tonnes of oil equivalent [toe], megawatt hours [MWh] or specific units of fuel produced)
Alternative Definitions	Accumulated quantity of solid waste from energy production
Agenda 21	Chapter 21: Environmentally sound management of solid wastes and sewage-related issues Chapter 4: Changing consumption patterns

POLICY RELEVANCE

(a) Purpose: The main purpose of this indicator is to provide information on the amount and type of solid waste generated each year by the energy sector and for which proper disposal facilities are needed.

(b) Relevance to Sustainable Development: From extraction of energy through to final use, the energy sector generates specific types of waste; for example, waste from coal mining, waste from processing of fuels and from combustion of fuel, etc. Volumes of mining waste tend to be large, and the nature of the waste makes it a safety hazard. If not properly secured, it can be susceptible to fire, to landslide and to the leaching of heavy metals and other pollutants into water and soil. In developing countries, scavenging on coal slag tips is common, leading to accidents and other health problems. In addition, large volumes of waste take up considerable space, blight the landscape and can spoil local wildlife habitats. For all waste types, inadequate storage and disposal can also lead to contamination of water bodies and soil through runoff and leaching. Moreover, much of the waste can potentially be used as a raw material — for example, as a building aggregate, which could reduce the need for quarrying, etc. — so that the non-use of this potential raw material represents a waste of resources.

(c) International Conventions and Agreements: There are no specific international agreements addressing the issue of solid waste from energy production or use. Agenda 21 calls on developed countries to take the lead in promoting and implementing more sustainable consumption and production patterns, which are also priority areas for the Johannesburg Plan of Implementation.

(d) International Targets/Recommended Standards: Some countries have set national targets for the reduction of solid waste within a specified time frame. In general, proposed measures for dealing with waste range from the introduction of cleaner technology and waste minimization to reuse, recycling, incineration and, when all other options have been exhausted, landfill.

(e) Linkages to Other Indicators: This indicator is linked to other economic and environmental indicators, including indigenous energy production, energy use, energy intensity, energy mix, energy supply efficiency, accumulated quantity of solid wastes to be managed, land area taken up by waste dumping, etc.

METHODOLOGICAL DESCRIPTION

(a) Underlying Definitions and Concepts: For the purpose of this indicator, the energy sector includes the following activities:

- Extraction of crude oil, natural gas, coal, lignite, peat, oil shales and other primary fuels. Harvesting of wood for fuel and extraction of uranium are not included.
- Conditioning of primary fuels (e.g. production of coal and lignite briquettes, refining of petroleum products).
- Electricity generation in public supply conventional thermal power plants, including combined heat and power plants. Enterprises that produce electricity exclusively for their own use are not included. Activities related to the functioning of nuclear power stations are specifically excluded.

Waste is defined as any substance or object that the holder discards or intends to discard. It is, therefore, perceived to have no commercial value to the producer. This does not preclude its being of value to some other party.

Solid waste from the energy sector is limited to waste that results directly from the normal functioning of that sector. Included are waste from coal and lignite mining and upgrading (tails); waste from oil and gas extraction and from refineries; combustion waste from thermal power stations (bottom ash, flying ash, slug); waste from the incineration of industrial and municipal waste, when these are used as a fuel in power stations; and waste from air pollution abatement technologies (sludge from scrubbers, spent catalysts). Non-regular waste such as decommissioned oil/gas rigs, power stations, refineries and other machinery should be reported separately, as these are exceptional events requiring special disposal measures. For the purpose of this indicator, radioactive waste and (scrapped) road vehicles, railway wagons and sea-going vessels[2] belonging to the energy industry are excluded.

(b) Measuring Methods: For the energy sector, the amount of normal waste can most easily be measured by weight as it leaves the energy production facility. In the case of mining waste, which normally is stored on-site, the amount can be estimated based on the quantity of coal or lignite extracted. The estimation method should be revised regularly to take into account new extraction methods and changes in the seam. Where relevant, the amount of incineration waste generated may be estimated based on the ash content of the coal or lignite. It is important for this indicator to be policy relevant; therefore, the different types of waste should be reported separately to highlight the main areas where action is needed.

The waste generated should be presented in absolute terms (tonnes), which gives an indication of the scale of the problem, and in terms of waste generated per unit of energy produced, which allows the effects of reduction measures to be assessed. In this case, it is important that the waste for each process be divided by the energy resulting from that process only. Under no circumstances should any attempt be made to aggregate all wastes and all energy produced from the different processes, as this will result in double and treble counting of some energy sources and will present a false picture.

The energy produced can be expressed in specific units of fuel produced (i.e. tonnes for coal, lignite and petroleum; cubic metres for gas; MWh for electricity), or in energy units (terajoules [TJ], MWh or toe, based on gross calorific value).

(c) Limitations of the Indicator: Solid waste generation from energy use, particularly waste from mining activities, is not always monitored at source and may have to be estimated based on coefficients. In this case, the waste generated per unit of energy produced will remain unchanged, unless the coefficients are changed. The indicator does not distinguish between toxic and hazardous wastes, and those that are more benign. It is often confused with the amount of solid waste disposed of, which is measured by recording the weight or volume of waste disposed of at a disposal or treatment site.

(d) Alternative Definitions/Indicators: The basic waste data could be presented on their own or as the accumulated waste — ideally the waste accumulated since operations started, but more realistically that accumulated since a fixed base year.

ASSESSMENT OF DATA

(a) Data Needed to Compile the Indicator: Data on the production of waste at source, as well as data on primary energy production, output from refineries and electricity generated from fossil fuels and other combustible fuels.

(b) National and International Data Availability: In general, waste statistics are of very poor quality, and the share of solid waste from energy production may be

[2] Transport equipment is considered to belong to the transport sector and thus is excluded from the definition of waste from the energy sector. If such equipment were included, the figures could be manipulated and waste could be 'reduced' by simply outsourcing transport activities, with no real impact on the quantities of waste generated.

difficult to obtain. Available data are scattered and consist of only rough estimates. In the European Union, data on industrial waste will be regularly collected with the implementation of the Waste Statistics Regulation.

(c) Data References: In some countries, data on the volume of waste removed from energy-producing facilities are monitored by waste-collection contractors. However, this may not be all the waste generated (see above).

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ENV8: Ratio of solid waste properly disposed of to total generated solid waste

Brief Definition	Amount of waste generated by the energy sector that has been properly disposed of, expressed as a percentage of the volume of total solid waste produced by the energy sector
Units	Percentage
Alternative Definitions	Amount of waste generated by the energy sector awaiting proper disposal; capacity of existing energy-related solid waste disposal and treatment facilities
Agenda 21	Chapter 4: Changing consumption patterns Chapter 21: Environmentally sound management of solid wastes and sewage-related issues

POLICY RELEVANCE

(a) Purpose: The main purpose of this indicator is to assess the extent of proper disposal of solid waste from the energy sector.

(b) Relevance to Sustainable Development: From extraction of energy through to final use, the energy sector generates specific types of waste; for example, waste from coal mining, waste from processing of fuels and from combustion of fuel, etc. Volumes of mining waste tend to be large, and the nature of the waste makes it a safety hazard. If not properly treated or disposed of, it can be susceptible to fire, to landslide and to the leaching of heavy metals and other pollutants into water and soil. In developing countries, scavenging on coal slag tips is common, leading to accidents and other health problems. In addition, large volumes of waste take up considerable space, blight the landscape and can spoil local wildlife habitats. For all waste types, inadequate storage and disposal can also lead to contamination of water bodies and soil through runoff and leaching.

(c) International Conventions and Agreements: There are no specific international agreements addressing the issue of solid waste from energy production or use. Agenda 21 calls on developed countries to take the lead in promoting and implementing more sustainable consumption and production patterns, which are also priority areas for the Johannesburg Plan of Implementation.

(d) International Targets/Recommended Standards: Some countries have set national targets for the reduction of solid waste within a specified time frame. In general, proposed measures for dealing with waste range from the introduction of cleaner technology and waste minimization to reuse, recycling, incineration and, when all other options have been exhausted, landfill.

(e) Linkages to Other Indicators: This indicator is specifically linked to the indicator on solid waste generation to units of energy produced. It is also linked to other economic and environmental indicators including indigenous energy production, energy use per capita, energy intensity, energy mix, energy supply efficiency, accumulated quantity of solid wastes to be managed, land area taken up by waste dumping, etc.

METHODOLOGICAL DESCRIPTION

(a) Underlying Definitions and Concepts: For the purpose of this indicator, the energy sector includes the following activities:

- Extraction of crude oil, natural gas, coal, lignite, peat, oil shales and other primary fuels. Harvesting of wood for fuel and extraction of uranium are not included.
- Conditioning of primary fuels (e.g. production of coal and lignite briquettes, refining of petroleum products).
- Electricity generation in public supply conventional thermal power plants, including combined heat and power plants. Enterprises that produce electricity exclusively for their own use are not included. Activities related to the functioning of nuclear power stations are specifically excluded.

Waste is defined as any substance or object that the holder discards or intends to discard. It is, therefore, perceived to have no commercial value to the producer. This does not preclude its being of value to some other party.

Solid waste from the energy sector is limited to waste that results directly from the normal functioning of that sector. Included are waste from coal and lignite mining and upgrading (tails); waste from oil and gas extraction and from refineries; combustion waste from thermal power stations (bottom ash, flying ash, slug); waste from the incineration of industrial and municipal waste, when these are used as a fuel in power stations; and waste from air pollution abatement technologies (sludge from scrubbers, spent catalysts). Non-regular waste such as decommissioned oil/gas rigs, power stations, refineries and other machinery should be reported separately, as these are exceptional events requiring special disposal measures. For the purpose of this indicator, radioactive waste and (scrapped) road vehicles, railway wagons and sea-going vessels[3] belonging to the energy industry are excluded.

'Properly disposed of' refers to

- Recycling or reuse of waste;
- Incineration in incinerators fitted with appropriate filters, etc., to remove noxious emissions;
- Solidification, so as to prevent landslide; and
- Disposal in secured and lined landfill sites and other sites where measures are in place to avoid runoff and uncontrolled combustion.

(b) Measuring Methods: To obtain a reasonable estimation of the proper disposal of waste, it is important to have an inventory of (energy) waste treatment and disposal facilities, whether on-site or at separate facilities that can also dispose of other types of waste. The weight of (energy) waste properly disposed of can most easily be measured as it enters the waste disposal or treatment facility. In the case of mining waste, which normally is stored on-site, the amount can be estimated based on the availability of adequate storage or treatment facilities on-site and on the percentage of waste generated that is sent to those facilities. For this indicator, it is important that the different types of waste be reported separately to highlight the main waste types for which proper disposal facilities are needed.

(c) Limitations of the Indicator: The expression 'properly disposed of' will have different meanings in different countries, and therefore the indicator will not necessarily mean the same thing everywhere. However, as use of this indicator is mainly internal, this will not pose a major problem. The indicator does not distinguish between toxic and hazardous wastes, and those that are more benign. For this reason, it is important to break the indicator down into the different types of waste.

(d) Alternative Definitions/Indicators: Two alternative indicators are proposed:

- Amount of waste generated by the energy sector awaiting proper disposal.
- Capacity of existing energy-related solid waste disposal and treatment facilities as a percentage of waste generated. This information is likely to be

[3] Transport equipment is considered to belong to the transport sector and thus is excluded from the definition of waste from the energy sector. If such equipment were included, the figures could be manipulated and waste could be 'reduced' by simply outsourcing transport activities, with no real impact on the quantities of waste generated.

more easily available, as in many countries these facilities are licensed or at least subject to planning permission.

ASSESSMENT OF DATA

(a) Data Needed to Compile the Indicator: Data on the production of waste at source and on the quantities delivered to waste treatment and disposal facilities.

(b) National and International Data Availability: In general, waste statistics are of very poor quality, and the share of solid waste from energy production may be difficult to obtain. Available data are scattered and consist of only rough estimates. In the European Union, data on industrial waste and on waste treatment facilities will be regularly collected with the implementation of the Waste Statistics Regulation.

(c) Data Reference: Many waste disposal facilities charge by weight for the treatment and disposal of waste. Therefore, these quantities should be readily available. However, this may not be all the waste treated, as some waste will be treated and disposed of on-site, without the intervention of outside contractors.

REFERENCES

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ENV9: Ratio of solid radioactive waste to units of energy produced

Brief Definition	Radioactive waste arisings from nuclear fuel cycles or other fuel cycles per unit of energy produced. Waste arisings destined for disposal in solid form are classified and categorized according to national definitions or as proposed here. These quantities consider all radioactive wastes from energy fuel cycles, including mining, milling, energy generation and other related processes. This indicator represents a set of indicators that includes one for each type of radioactive waste
Units	Cubic metres (m^3) of radioactive waste destined for disposal in solid form and tonnes of heavy metal (tHM) for spent fuel per terawatt hour (TWh) of electricity produced or tonne of oil equivalent (toe) or exajoule (EJ) of final energy produced in a selected period of time (e.g. several years or lifetime of facility)
Alternative Definitions	Generation of radioactive waste
Agenda 21	Chapter 22: Safe and environmentally sound management of radioactive wastes

POLICY RELEVANCE

(a) Purpose: The purpose of this indicator is to account for the amounts of various radioactive waste streams that arise from the nuclear fuel cycle in particular and from other fuel cycles per unit of energy produced.

(b) Relevance to Sustainable Development: Energy is a key to sustainable development, and the generation of all types of solid waste, and in particular solid radioactive waste, should be minimized. In addition, and as described in the chapter on radioactive waste (Chapter 22) of Agenda 21, it is important to ensure that radioactive wastes are safely managed, transported, stored and disposed of, with a view to protecting human health and the environment in the short and long terms.

Radioactive waste is an environmental concern associated with different energy generation systems and in particular with nuclear power. To protect human health and the environment, waste management strategies and technologies exist and are being employed, especially by the nuclear industry. Fundamental principles of radioactive waste management involve minimization of waste arisings and systematic management of the treatment, conditioning, storage and disposal of such waste. Other fuel chains besides nuclear produce radioactive waste; thus, this indicator should also be applied to those fuel chains.

(c) International Conventions and Agreements: International standards and criteria exist for the nuclear energy industry in the form of recommendations by the International Commission on Radiological Protection (ICRP) and also in the Requirements and Guides of the Safety Standards of the International Atomic Energy

Agency (IAEA). In 1995, the IAEA published *The Principles of Radioactive Waste Management* (Safety Series No. 111-F). One of the nine principles specified in this report states that 'Radioactive waste shall be managed in such a way that will not impose undue burdens on future generations'. The principles set forth in this publication provided the technical basis for the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management. This convention, which entered into force in June 2001, requires Contracting Parties to account for spent fuel and radioactive waste inventories. This convention binds Parties to manage spent nuclear fuel and radioactive wastes using the most appropriate waste management practices.

(d) International Targets/Recommended Standards: The IAEA has established Safety Standards (Fundamentals, Requirements and Guides) applicable to the management of radioactive wastes generated in nuclear energy facilities. It has also established the International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources, which are consistent with recommendations of the ICRP. No comparable international recommended standards or targets exist for the radioactive waste generated in non-nuclear energy industries.

(e) Linkages to Other Indicators: This indicator is linked to other indicators related to radioactive waste, such as the 'Ratio of solid radioactive waste awaiting disposal to total generated solid radioactive waste' and 'Management of radioactive waste, ISD-RW'.[4]

METHODOLOGICAL DESCRIPTION

(a) Underlying Definitions and Concepts: At present, there are no universally accepted strict categorizations for and definitions of radioactive waste, although some countries do have strict definitions. Nevertheless, in 1994 the IAEA published a guide (Safety Series No. 111-G-1.1) on waste classification for all waste types arising from the nuclear cycle. However, capacity building and improved guidance are required to apply this class scheme, and a common international framework on how to apply the classes to waste types is necessary. No definitions, concepts or classifications exist for radioactive waste arising from non-nuclear processes and activities.

For nuclear fuel cycles, if national classifications are not available, it is proposed that the radioactive waste in solid form be classified into three different categories: high-level radioactive waste (HLW); low- and intermediate-level radioactive waste (LILW), long lived (LL) and short lived (SL); and spent fuel arisings. The vast majority of all radioactive waste from the nuclear power fuel cycle chain is low level, and safe disposal sites for this type of waste have been in operation in numerous countries for many years. Disposal sites for HLW and other long-lived waste are under development in some countries. LILW is waste for which the heat generated is negligible and does not need to be taken into account during treatment and disposal. HLW is waste for which heat generation is significant and must be considered in all

4 The latter is part of the United Nations Department of Economic and Social Affairs (UNDESA) ISD set of indicators; its description is available at http://www-newmdb.iaea.org/ and http://www.un.org/esa/sustdev/natlinfo/indicators/isdms2001/isd-ms2001economicB.htm#radioactivewaste.

the management steps. The concentration of long-lived alpha-emitting radionuclides determines whether the LILW is classed as SL or LL. Additionally, radioactive waste includes spent fuel, although in some countries it is not considered a waste stream and is routinely reprocessed (or stored for future use) in order to recycle the uranium and plutonium (as fresh fuel) and to remove the fission product, which is vitrified and constitutes the HLW stream. The indicator described by this methodology sheet in fact represents a set of indicators, since each type of radioactive waste needs to be assessed separately.

(b) Measuring Methods: For radioactive waste from nuclear cycles in packaged/conditioned form, the volume should be the actual volume in m^3 as recorded in the appropriate waste package registry; and for spent fuel, in tHM. For radioactive waste not yet in conditioned form, the volumes used should be those based on the conditioning method assumed the most likely to be used later for disposal. The indicator can be developed at three levels according to the definition of boundaries: (i) at the plant level, (ii) at the generating system level and (iii) at the overall fuel cycle or energy system level. At the plant level, the indicator provides a tool to weigh the environmental sustainability of innovative technologies, especially with respect to innovative nuclear reactors and fuel cycles. At this level, the indicator is readily defined by the technical specifications unique to each technology. At the generating system level, the indicator considers the net waste after reprocessing or any other processes that either increase or reduce the net radioactive waste. At the overall fuel cycle level, the indicator assesses the overall waste generation from front end to back end, including all intermediate processes, and through time from start-up to decommissioning. At this level, the measuring of the environmental sustainability is the most comprehensive, but the measuring method remains to be fully defined. The indicator is defined, for each waste type and for each industry or activity, as the ratio of solid radioactive waste to energy produced. The waste is normalized with respect to the amount of energy produced in a selected period of time (several years or for the life of the facility).

Efforts are necessary worldwide for the identification, measuring and monitoring of radioactive waste generated from non-nuclear activities and processes. Appropriate recommended standards, targets and measuring methods need to be developed for the effective management of the radioactive waste generated from these sources.

(c) Limitations of the Indicator: Differences between countries may arise due to differences in the classification system used in establishing national inventories.

Defining the indicator at the overall fuel cycle level requires an elaborated methodology that is not yet fully defined.

(d) Alternative Definitions/Indicators: Generation of radioactive waste.

ASSESSMENT OF DATA

(a) Data Needed to Compile the Indicator: The volumes of the various radioactive waste types arising annually:

- High-level radioactive waste (HLW).
- Low- and intermediate-level radioactive waste, long lived (LILW-LL).

- Low- and intermediate-level radioactive waste, short lived (LILW-SL).
- Spent fuel arisings.
- Radioactive waste from non-nuclear processes and activities.

(b) National and International Data Availability: At the national level, the volume of radioactive waste arisings from nuclear facilities could be obtained from the waste accountancy records maintained by the various waste generators or, in consolidated form, from national regulatory bodies. Almost one-third of the IAEA Member States keep some type of national radioactive waste registry. The Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management requires Contracting Parties to report their radioactive waste inventories within their national reports. Through this mechanism, both the availability and the quality of data are likely to increase over time. A secondary source may be databases managed by international organizations such as the IAEA or the Organisation for Economic Co-operation and Development (OECD)/ Nuclear Energy Agency (NEA). Currently, with perhaps the exception of country data on spent fuel arisings, comprehensive country data from nuclear fuel cycles on radioactive waste are not readily available.

Data on radioactive waste from other fuel chains are not usually available.

(c) Data References: The primary source for data includes national or state-level governmental organizations. The IAEA maintains the Net Enabled Waste Management Database (NEWMDB), which contains information on national radioactive waste management programmes, plans and activities, relevant laws and regulations, policies and radioactive waste inventories (http://www-newmdb.iaea.org/). The European Commission compiles data for the European Union Member States and for the Accession Countries.

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<u>ENV10:</u> Ratio of solid radioactive waste awaiting disposal to total generated solid radioactive waste

Brief Definition	This indicator is a measure of the accumulated quantities of solid radioactive waste awaiting near-surface or geological disposal from all steps in the nuclear and non-nuclear fuel cycles. These quantities include all radioactive wastes originating from energy fuel cycles, including mining, milling, energy generation and other related processes. Radioactive wastes in solid form are classified and categorized according to national definitions or as proposed here. This indicator represents a set of indicators that includes one for each type of radioactive waste
Units	Percentage based on cubic metres (m^3) of solid radioactive waste (or tonnes of heavy metal [tHM] for spent fuel) awaiting disposal over total generated radioactive waste
Alternative Definitions	Accumulated quantity of radioactive waste awaiting disposal or ratio of radioactive waste properly disposed of to total generated radioactive waste
Agenda 21	Chapter 22: Safe and environmentally sound management of radioactive wastes

POLICY RELEVANCE

(a) Purpose: By providing the share of radioactive waste still awaiting disposal, this indicator shows the relative status of the existing radioactive waste at any given time for any energy fuel cycle. Increasing shares of radioactive waste awaiting disposal over time would indicate an increasing need in the long term for appropriate disposal options, such as near-surface or geological disposal.

(b) Relevance to Sustainable Development: Energy is a key to sustainable development, and the appropriate management of solid radioactive waste generated by energy fuel cycles is a major priority. As described in the chapter on radioactive waste (Chapter 22) of Agenda 21, it is important to ensure that radioactive wastes are safely managed, transported, stored and disposed of, with a view to protecting human health and the environment in the short and long terms.

Radioactive waste is an environmental concern associated with different energy generation systems and in particular with nuclear power. To protect human health and the environment, waste management strategies and technologies exist and are being employed, especially by the nuclear industry. Fundamental principles of radioactive waste management involve minimization of waste arisings and systematic management of the treatment, conditioning, storage and disposal of such waste. Waste management strategies are designed to confine and contain the radionuclides within a system of engineered and natural barriers. Other fuel chains besides nuclear produce some radioactive waste; thus, this indicator should also be applied to those fuel chains.

(c) International Conventions and Agreements: International standards and criteria exist for the nuclear industry in the form of recommendations by the International Commission on Radiological Protection (ICRP) and also in the Requirements and Guides of the Safety Standards of the International Atomic Energy Agency (IAEA). In 1995, the IAEA published *The Principles of Radioactive Waste Management* (Safety Series No. 111-F). One of the nine principles specified in this report states that 'Radioactive waste shall be managed in such a way that will not impose undue burdens on future generations'. The principles set forth in this publication provided the technical basis for the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management. This convention, which entered into force in June 2001, requires Contracting Parties to account for spent fuel and radioactive waste inventories. The convention also binds Parties to manage spent nuclear fuel and radioactive wastes using the most appropriate waste management practices.

(d) International Targets/Recommended Standards: International targets do not exist. Nationally, targets can be derived from the relevant national radioactive waste management programmes. No recommended standards or targets exist for the radioactive waste generated in non-nuclear energy processes and activities.

(e) Linkages to Other Indicators: This indicator is linked to other indicators related to radioactive waste, such as 'Ratio of solid radioactive waste to units of energy produced' and 'Management of radioactive waste, ISD-RW'.[5]

METHODOLOGICAL DESCRIPTION

(a) Underlying Definitions and Concepts: At present, there are no universally accepted strict categorizations for and definitions of radioactive waste, although some countries do have strict definitions. Nevertheless, in 1994 the IAEA published a guide (Safety Series No. 111-G-1.1) on waste classification for all waste types arising from the nuclear cycle. However, capacity building and improved guidance are required to apply this class scheme, and a common international framework on how to apply the classes to waste types is necessary. No definitions, concepts or classifications exist for radioactive waste arising from non-nuclear processes and activities.

For nuclear fuel cycles, if national classifications are not available, it is proposed that the radioactive waste in solid form be classified into three different categories: high-level radioactive waste (HLW); low- and intermediate-level radioactive waste (LILW), long lived (LL) and short lived (SL); and spent fuel arisings. The vast majority of all radioactive waste from the nuclear power fuel cycle chain is low level, and safe disposal sites for this type of waste have been in operation in numerous countries for many years. Disposal sites for HLW and other long-lived waste are

[5] The latter is part of the United Nations Department of Economic and Social Affairs (UNDESA) ISD set of indicators; its description is available at http://www-newmdb.iaea.org/ and http://www.un.org/esa/sustdev/natlinfo/indicators/isdms2001/isd-ms2001economicB.htm#radioactivewaste.

under development in some countries. LILW is waste for which the heat generated is negligible and does not need to be taken into account during treatment and disposal. HLW is waste for which heat generation is significant and must be considered in all the management steps. The concentration of long-lived alpha-emitting radionuclides determines whether the LILW is classed as SL or LL. Additionally, radioactive waste includes spent fuel, although in some countries it is not considered a waste stream and is routinely reprocessed (or stored for future use) in order to recycle the uranium and plutonium (as fresh fuel) and to remove the fission product, which is vitrified and constitutes the HLW stream. The indicator described by this methodology sheet in fact represents a set of indicators, since each type of radioactive waste needs to be assessed separately.

(b) Measuring Methods: For radioactive waste from nuclear fuel cycles in packaged/conditioned form, broken down into the different waste types according to national classifications and regulations or as specified above, the basic unit should be the actual volume in m^3; for spent fuel, tHM. For radioactive waste not yet in conditioned form, the volumes used should be those based on the conditioning method assumed the most likely to be used later for disposal. The indicator is defined, for each waste type and for each industry or activity, as the ratio of radioactive waste awaiting disposal to the corresponding total generated radioactive waste.

Efforts are necessary worldwide for the identification, measuring and monitoring of radioactive waste generated from non-nuclear processes and activities. Appropriate recommended standards, targets and measuring methods need to be developed for the effective management of the radioactive waste generated from these sources.

(c) Limitations of the Indicator: There is an inevitable time lag between the moment that the waste arises and its disposal. In the case of spent fuel and HLW, this time lag can be on the order of several decades, and therefore trends should be interpreted carefully.

Some differences among countries may arise due to differences in the classification system used in establishing national inventories.

(d) Alternative Definitions/Indicators: Accumulated quantity of radioactive waste awaiting disposal; also, ratio of radioactive waste properly disposed of to total generated radioactive waste.

ASSESSMENT OF DATA

(a) Data Needed to Compile the Indicator: The accumulated quantities of the various radioactive waste types generated and awaiting proper disposal as defined nationally or classified as

- High-level radioactive waste (HLW);
- Low- and intermediate-level radioactive waste, long lived (LILW-LL);
- Low- and intermediate-level radioactive waste, short lived (LILW-SL);
- Spent fuel; or
- Radioactive waste from non-nuclear processes and activities.

(b) National and International Data Availability: At the national level for nuclear fuel cycles, the accumulated volume of radioactive waste awaiting disposal could be obtained from the waste accountancy records maintained by the various waste generators or, in consolidated form, from national regulatory bodies. At present, almost one-third of the IAEA Member States keep some kind of national radioactive waste registry. The Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management requires Contracting Parties to report their radioactive waste inventories within their national reports. Through this mechanism, both the availability and the quality of data are likely to increase over time. A secondary source may be databases managed by international organizations such as the IAEA or the Organisation for Economic Co-operation and Development (OECD)/Nuclear Energy Agency (NEA). Currently, with perhaps the exception of country data on spent fuel arisings, comprehensive country data from nuclear fuel cycles on radioactive waste awaiting disposal are not readily available.

Data on radioactive waste from other fuel chains are not usually available.

(c) Data References: The primary source for data includes national or state-level governmental organizations. The IAEA maintains the Net Enabled Waste Management Database (NEWMDB), which contains information on national radioactive waste management programmes, plans and activities, relevant laws and regulations, policies and radioactive waste inventories.[6] The European Commission compiles data for the European Union Member States and for the Accession Countries.

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[6] The NEWMDB internet site is http://www-newmdb.iaea.org/

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RELATED INTERNET SITES

- CONCAWE (CONservation of Clean Air and Water in Europe — The Oil Companies' European Organization for Environmental and Health Protection): www.concawe.be
- EEA (European Environment Agency): http://www.eea.eu.int
- EEA — Energy and environmental indicators: http://themes.eea.eu.int/Sectors_and_activities/energy
- EEA — First indicators report on energy and environment in the European Union: http://reports.eea.eu.int/environmental_issue_report_2002_31/en
- EPA (United States Environmental Protection Agency): http://www.epa.gov/ epaoswer/other/mining/minedock/id.htm
- EC (European Commission) — Eurostat: http://europa.eu.int/comm/eurostat/
- EC — Eurostat, statistical information: http://epp.eurostat.cec.eu.int/portal/page?_pageid=1090,1137397&_dad=portal&_schema=PORTAL
- EC — General Directorate Transport & Energy: http://europa.eu.int/comm/dgs/energy_transport/index_en.html
- EC — Joint Research Centre, SIP project: http://esl.jrc.it/envind/sip/en/sip_en01.htm
- EC — Joint Research Centre, Waste treatment and disposal technologies: http://eippcb.jrc.es/pages/FActivities.htm
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- IAEA (International Atomic Energy Agency): http://www.iaea.org/
- IAEA — Net Enabled Waste Management Database: http://www-newmdb.iaea.org/
- IAEA — Planning and Economic Studies Section: Analysis for Sustainable Energy Development: http://www.iaea.org/OurWork/ST/NE/Pess

- ICRP (International Commission on Radiological Protection):
  http://icrp.org/
- IEA (International Energy Agency):
  http://www.iea.org
- IEA — Statistics:
  http://www.iea.org/statist/index.htm.
- IPCC (Intergovernmental Panel on Climate Change):
  http://www.ipcc.ch
- IPCC — Technical support:
  http://www.ipcc.nggip.iges.or.jp
- ISWA (International Solid Waste Association):
  http://www.iswa.org/
- ITTO (International Tropical Timber Organization):
  http://www.itto.or.jp/
- NEA (Nuclear Energy Agency):
  http://www.nea.fr/
- OECD (Organisation for Economic Co-operation and Development):
  http://www.oecd.org/
- UNCSD (United Nations Commission on Sustainable Development):
  www.un.org/esa/sustdev/csd
- UNDESA (United Nations Department of Economic and Social Affairs):
  http://www.un.org/esa/desa.htm
- UNDESA — Indicators of Sustainable Development:
  http://www.un.org/esa/sustdev/natlinfo/indicators/isd.htm
- UNDESA — Indicators of Sustainable Development, Methodology Sheets:
  http://www.un.org/esa/sustdev/natlinfo/indicators/isdms2001/
- UNEP (United Nations Environment Programme):
  http://www.unep.org/
- UNFCCC (United Nations Framework Convention on Climate Change):
  http://www.unfccc.int
- UNITAR (United Nations Institute for Training and Research), Publications:
  www.unitar.org/ccp/pubs/index.htm
- UNITAR — Other emissions:
  www.unitar.org/cwm/publications/prtr.htm
- UNSD (United Nations Statistics Division):
  http://www.un.org/Depts/unsd
- World Bank:
  http://www.worldbank.org/data

- WEC (World Energy Council):
  http://www.worldenergy.org
- WHO (World Health Organization):
  http://www.who.org
- World Resources Institute:
  http://www.wri.org/
- WSSD (World Summit on Sustainable Development):
  http://www.johannesburgsummit.org/

ANNEX 1: GLOSSARY OF SELECTED TERMS

Acidification is the change in an environment's natural chemical balance caused by an increase of acidic elements.

Agenda 21 is a comprehensive plan of action to be taken globally, nationally and locally by the United Nations system, governments and major groups in every area in which human activities have an impact on the environment.

Coal includes primary solid fuels such as hard coal and lignite, and derived fuels (including patent fuel, coke oven coke, gas coke, coke oven gas and blast furnace gas). Peat is also included in this category.

Combustible renewables and waste (CRW) consists of biomass (wood, vegetal waste, ethanol) and animal products (animal materials/wastes and sulphite lyes), municipal waste (wastes produced by the residential, commercial and public service sectors that are collected by local authorities for disposal in a central location for the production of heat and/or power) and industrial waste.

Critical load is the maximum load that a given system can tolerate before failing.

Crude oil comprises crude oil, natural gas liquids, refinery feedstocks and additives, as well as other hydrocarbons such as synthetic oils, mineral oils extracted from bituminous minerals and oils from coal and natural gas liquefaction.

Gas includes natural gas (excluding natural gas liquids) and gas works gas.

Global warming potential describes the cumulative effect of the different greenhouse gases. For example, over a period of 100 years, 1 tonne of methane will have a warming effect equivalent to 21 tonnes of carbon dioxide, and 1 tonne of nitrous oxide will have the effect of 310 tonnes of carbon dioxide.

Greenhouse gases act like a blanket around the Earth or like the glass roof of a greenhouse; they trap heat from sunlight and keep the Earth some 30ºC warmer than it would be otherwise. The Kyoto Protocol covers a basket of six greenhouse gases produced by human activities: carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride.

Hydro refers to the energy content of the electricity produced in hydropower plants. Hydro output excludes output from pumped storage plants. Electricity production from hydropower is accounted for by using the factor 1 terawatt hour (TWh) equals 0.086 million tonnes of oil equivalent (Mtoe).

Non-combustible renewables include geothermal, solar, wind, hydro, tide and wave energy. For geothermal energy, the energy quantity is the enthalpy of the geothermal heat entering the process. For solar, wind, hydro, tide and wave energy, the quantities entering electricity generation are equal to the electrical energy generated. Electricity is accounted for at the same heat value as electricity in final consumption (i.e. 1 TWh equals 0.086 Mtoe). Direct use of geothermal and solar heat, and heat from heat pumps is also included here.

Nuclear represents the primary heat equivalent of the electricity produced by a nuclear power plant with an average thermal efficiency of 33%, that is, 1 TWh equals 0.261 Mtoe.

Particulates: Terms commonly associated with particulate matter are particulate matter with a diameter less than 10 μm (PM10), total suspended particulate (TSP), primary particulate and secondary particulate. PM10 in the atmosphere can result from direct particulate emissions (primary PM10) or from emissions of gaseous particulate precursors that are partly transformed into particles by chemical reactions in the atmosphere (secondary PM10). TSP consists of matter emitted from sources in solid, liquid and vapour forms, but existing in the ambient air as particulate solids or liquids.

Petroleum products comprise refinery gas, ethane, liquefied petroleum gas (LPG), aviation gasoline, motor gasoline, jet fuels, kerosene, gas/diesel oil, heavy fuel oil, naphtha, white spirit, lubricants, bitumen, paraffin waxes, petroleum coke and other petroleum products.

Purchasing power parities (PPP) are the rates of currency conversion that equalize the purchasing power of different currencies. A given sum of money, when converted into different currencies at the PPP rates, buys the same basket of goods and services in all countries. In other words, PPPs are the rates of currency conversion that eliminate the differences in price levels between different countries.

Tonne is equivalent to 1000 kilograms.

Total final consumption (TFC) refers to the sum of consumption by the different end-use sectors and thus excludes energy consumed or losses incurred in the conversion, transformation and distribution of the various energy carriers.

Total primary energy supply (TPES) is made up of production of primary energy — for example, coal, crude oil, natural gas, nuclear, hydro, other non-combustible and combustible renewables — plus imports and less exports of all energy carriers, less international marine bunkers and finally corrected for net changes in energy stocks. Production refers to the first stage of production. International trade of energy commodities is based on the general trade system; that is, all goods entering and leaving the national boundaries of a country are recorded as imports and exports, respectively. In general, data on stocks refer to changes in stocks of producers, importers and/or industrial consumers at the beginning and the end of the year.

Volatile organic compounds (VOCs) are defined as any compound of carbon (excluding carbon monoxide, carbon dioxide, carbonic acid, metallic carbides or carbonates, and ammonium carbonate) that participates in atmospheric chemical reactions. In some cases, the term non-methane volatile organic compound (NMVOC) is used to indicate that methane is exempt from the VOC categorization.

ANNEX 2: LIST OF ACRONYMS

EJ	exajoule
km	kilometre
km^2	square kilometre
kWh	kilowatt-hour
m	metre
m^3	cubic metre
mg	milligram
Mtoe	million tonnes of oil equivalent
MWh	megawatt hours
tHM	tonnes of heavy metal
TJ	terajoules
toe	tonnes of oil equivalent
TWh	terawatt hour

BOD	biochemical oxygen demand
COD	chemical oxygen demand
CRW	combustible renewables and waste
DPSIR	Driving forces, Pressures, State of the environment, Impacts, and societal Responses
DSR	driving force, state and response
EDI	energy development index
EISD	Energy Indicators for Sustainable Development
GDP	gross domestic product
GHG	greenhouse gas
GWP	global warming potential
HDI	Human Development Index
HLW	high-level radioactive waste
ISD	Indicators of Sustainable Development
ISED	Indicators for Sustainable Energy Development
LILW	low- and intermediate-level radioactive waste
LL	long lived
LNG	liquefied natural gas
LPG	liquefied petroleum gas
NCV	net calorific value
NGL	natural gas liquids
NMVOC	non-methane volatile organic compound
NOx	nitrogen oxides
PM	particulate matter
PM2.5	particulate matter with a diameter less than 2.5 μm
PM10	particulate matter with a diameter less than 10 μm
PPP	purchasing power parity
PSR	pressure-state-response
SL	short lived
SUV	sport utility vehicle
TFC	total final consumption

TOC	total organic carbon
TPES	total primary energy supply
TSP	total suspended particulate
VOC	volatile organic compound

APERC	Asia Pacific Energy Research Centre
CCE	Coordination Center for Effects
CDIAC	Carbon Dioxide Information Analysis Center
CSD	Commission on Sustainable Development
EC	European Commission
ECMT	European Conference of Ministers of Transport
EEA	European Environment Agency
Eurostat	Statistical Office of the European Communities
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
EMEP/MSC-W	EMEP's Meteorological Synthesizing Centre — West
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organization for Standardization
ITOPF	International Tanker Owners Pollution Federation Limited
MAHB	Major Accident Hazards Bureau
NEA	Nuclear Energy Agency
OECD	Organisation for Economic Co-operation and Development
OLADE	Organización Latinoamericana de Energía
UN	United Nations
UNCED	United Nations Conference on Environment and Development
UNDESA	United Nations Department of Economic and Social Affairs
UNECE	United Nations Economic Commission for Europe
UNEP	United Nations Environment Programme
UNICEF	United Nations Children's Fund
UNITAR	United Nations Institute for Training and Research
WEC	World Energy Council
WHO	World Health Organization
WMO	World Meteorological Organization

AMIS	Air Management Information System
CBD	Convention on Biological Diversity
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CLRTAP	Convention on Long-range Transboundary Air Pollution
CONCAWE	CONservation of Clean Air and Water in Europe — The Oil Companies' European Organization for Environmental and Health Protection
EMEP	Co-operative Programme for Monitoring and Evaluation of the Long-Range Transmission of Air Pollutants in Europe
EPER	European Pollutant Emission Register

GPA	Global Programme of Action for the Protection of the Marine Environment from Land-Based Activities
HELCOM	Helsinki Convention Baltic Marine Environment Protection Commission
ISIC	International Standard Industrial Classification system
JPOI	Johannesburg Plan of Implementation
MARS	Major Accident Reporting System
NECD	National Emission Ceiling Directive
NEWMDB	Net Enabled Waste Management Database
OSPAR	Oslo and Paris Conventions Commission
PRTR	(OECD) Pollutant Release and Transfer Register
UNCCD	United Nations Convention to Combat Desertification
UNCLOS	United Nations Convention on the Law of the Sea
UNFCCC	United Nations Framework Convention on Climate Change
WOAD	Worldwide Offshore Accident Database
WSSD	World Summit on Sustainable Development

ANNEX 3: A DECOMPOSITION METHOD FOR ENERGY USE INTENSITY INDICATORS[1]

Introduction

This annex provides an overview of a method that can be used to analyse energy-use developments in a disaggregated fashion. There are a number of journal publications that describe this method and related results.[2]

The indicators employed to analyse energy use intensity are constructed by combining energy data with data that describe factors driving consumption in end-use sectors. From these data, various types of energy intensities can be developed. Energy intensities are related to the inverse of energy efficiencies, but are not equivalent. The two are related in that the energy intensity of an activity or productive output summarizes the relationship between an overall measure of output and the energy used for a variety of processes towards that end. Each process (e.g. heating, motive power) involves one or more transformations of energy that can be described in terms of efficiencies.

Changes in intensities are affected by factors other than energy efficiency; therefore, analysing intensity trends provides important insights into how energy efficiency and other factors affect energy use.

The method described here distinguishes among three main components affecting energy use: activity levels, structure (the mix of activities within a sector) and energy intensities (energy use per unit of sub-sectoral activity). Depending on the sector, *activity* is measured either as value added, passenger-kilometres (km), tonne-km, population or built area. *Structure* divides activity further into industry sub-sectors, transportation modes or measures of residential end-use activity. Table A3.1 gives an overview of the various measures applied for activity, structure and energy intensities in each sector; Figure A3.1 illustrates the disaggregation into sectors, sub-sectors and end uses.

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1 The method presented here builds on the analytical framework developed under the International Energy Agency (IEA) Energy Indicator Project. Key findings of this work are presented in the IEA publication *Oil Crises and Climate Challenges: 30 Years of Energy Use in IEA Countries* (IEA 2004).

2 Selected references include the following: Krackeler et al. (1998); Schipper, Murtishaw, et al. (2001); Schipper, Unander, et al. (2001); Unander et al. (1999); Unander et al. (2004).

Table A3.1: Summary of Variables Used in the Energy Decomposition Method

Sector (*i*)	Sub-sector (*j*)	Activity (*A*)	Structure (S_j)	Intensity ($I_j = E_j/A_j$)
Household				
	Space Heat	Population	Floor area/capita	Heat[1]/floor area
	Water Heat	"	Persons/household	Energy/capita[2]
	Cooking	"	Persons/household	Energy/capita[2]
	Lighting	"	Floor area/capita	Electricity/floor area
	Appliances	"	Ownership[3]/capita	Energy/appliance[3]
Passenger Transport				
	Cars	Passenger-km	Share of total passenger-km	Energy/passenger-km
	Bus	"	"	"
	Rail	"	"	"
	Domestic Air	"	"	"
Freight Transport				
	Trucks	Tonne-km	Share of total tonne-km	Energy/tonne-km
	Rail	"	"	"
	Domestic Shipping	"	"	"
Service				
	Total Services	Services GDP	(Not defined)	Energy/GDP
Manufacturing				
	Paper and Pulp	Value added	Share of total value added	Energy/value added
	Chemicals	"	"	"
	Non-Metallic Minerals	"	"	"
	Iron and Steel	"	"	"
	Non-Ferrous Metals	"	"	"
	Food and Beverages	"	"	"
Other Industry				
	Agriculture and Fishing	Value added	Share of total value added	Energy/value added
	Mining	"	"	"
	Construction	"	"	"

[1]Adjusted for climate variations and for changes in the share of dwellings with central heating systems.
[2]Adjusted for dwelling occupancy (number of persons per household).
[3] Includes ownership and electricity use for six major appliances.

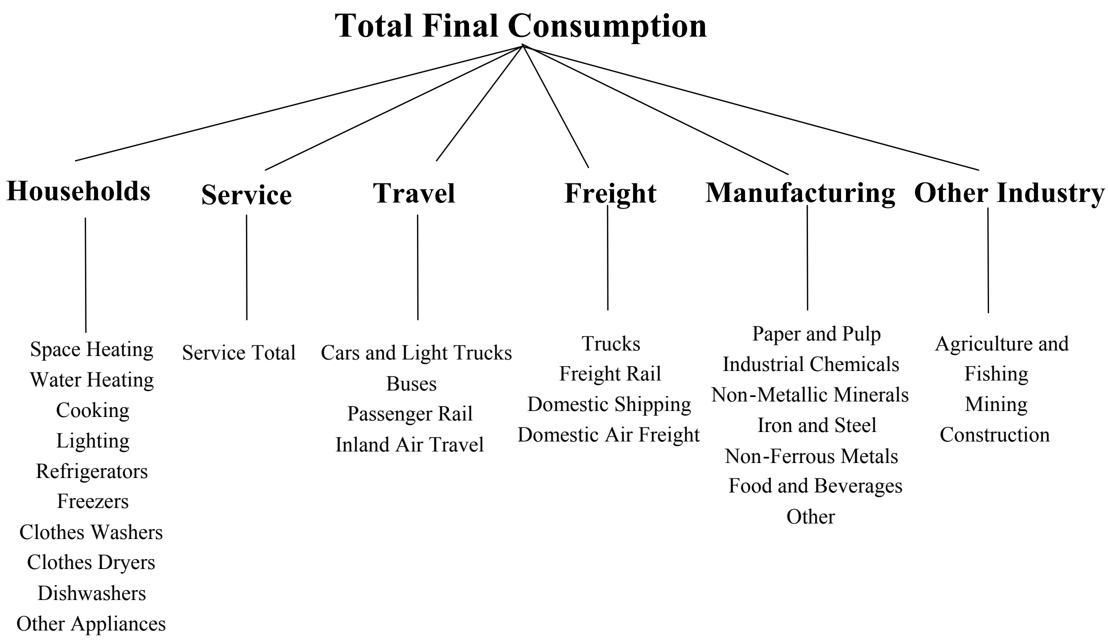

Figure A3.1. Disaggregation into Sectors, Sub-sectors and End Uses

Key Terms

Useful Energy: Delivered energy minus losses estimated for boilers, furnaces, water heaters and other equipment in buildings; used for estimates of heat provided in space and water heating.

Activity or Output: Basic unit of accounting for which energy is used; for example, in space heating, it is the area heated; in manufacturing, it is the production measured as value-added in real terms as in the output in tonnes of steel or number of widgets.

Energy Intensity: Energy 'consumed' per unit of activity or output.

Structure: Refers to the activity mix; for example, modal mix (trucks, rail, ships) in travel, energy end uses in households and the shares of each sub-sector in total manufacturing value added.

Energy Services: Implies actual services for which energy is used: heating a given amount of space to a standard temperature for a period of time, etc. Here, a measure of energy service demand in a sector is obtained from combined activity and structure measures.

The separation of impacts on energy use from changes in activity, structure and intensity is critical for policy analysis, as most energy-related policies target energy intensities and efficiencies, often by promoting new technologies. Accurately tracking changes in intensities helps measure the effects of these new technologies. To separate the effect of various components over time, a factoral decomposition is used where changes in energy use in a sector are analysed using the following equation:

$$\mathbf{E = A \sum_{j} S_{\mathit{j}} * I_{\mathit{j}}} \,. \tag{A3.1}$$

In this decomposition,

E represents total energy use in a sector;

A represents overall sectoral activity (e.g. value added in manufacturing);

S_j represents sectoral structure or mix of activities within a sub-sector j (e.g. shares of output by manufacturing sub-sector j); and

I_j represents the energy intensity of each sub-sector or end-use j (e.g. energy use/real US dollar value added),

where the index j denotes sub-sectors or end uses within a sector as shown in the second column in Table A3.1.

If indices for the changes in each of these components over time are established, they can be thought of as 'all else being equal' indices. They describe the evolution of energy use that would have taken place if all but one factor had remained constant at their base year (*t=0*) values.[3]

From this the *activity effect* can be calculated as the relative impact on energy use that would have occurred between year *t=0* and year *t* if the structure and energy intensities for a sector had remained fixed at base-year values while aggregate activity had followed its actual development:

$$\mathbf{A_t/A_0 = A_t \sum_{j} S_{j,o} * I_{j,0} \,/\, E_0} \,. \tag{A3.2}$$

Similarly, the hypothetical change in energy use given constant aggregate activity and energy intensities but varying sectoral structure — the *structure effect* — is

$$\mathbf{S_t/S_0 = A_0 \sum_{j} S_{j,t} * I_{j,0} \,/\, E_0} \,, \tag{A3.3}$$

and the proportional change in energy use given constant activity and structure but varying energy intensities — the *intensity effect* — is

$$\mathbf{I_t/I_0 = A_0 \sum_{j} S_{j,o} * I_{j,t} \,/\, E_0} \,. \tag{A3.4}$$

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[3] There are different index-number techniques that permit the analysis of this relationship over time. Here, the Laspeyeres indices approach is used. The Laspeyres approach yields a residual term as a result of interaction among the other factors in the decomposition. This means that the changes in the decomposition factors do not necessarily always add up exactly to the changes in energy use. In most cases, the residual term is relatively small compared to the effects of the other factors.

Thus through calculating the relative impact on energy use from changes in each of these components, the impacts on energy use related to improved end-use energy efficiency (reductions in energy intensities) can be isolated from changes derived from shifts in the activity and structure components.

The resulting indices from each sector defined above can be combined further and weighted at base-year values of energy use to measure the impact of changes in either energy intensities or economy-wide activity and structure components on overall energy use. With *E* in this case representing energy use at the national level, the decomposition equations take the form

$$\mathbf{E} = \sum_{i} \mathbf{A_i} * \sum_{j} \mathbf{S_{i,j}} * \mathbf{I_{i,j}} \ , \qquad \textbf{(A3.5)}$$

where the index *i* denotes the sectors listed in the first column in Table A3.1. By re-aggregating the decomposition terms to the national level, interesting comparisons can be made of developments in energy per unit of gross domestic product (GDP). If both sides of Equation (A3.5) are divided by GDP, then

$$\mathbf{E/GDP} = ((\sum_{i} \mathbf{A_i} * \sum_{j} \mathbf{S_{i,j}})/\mathbf{GDP}) * \sum_{i,j} \mathbf{I_{i,j}} \ . \qquad \textbf{(A3.6)}$$

The product of the activity effect (*A*) and the structure effect (*S*) can be defined as the *energy services* effect. Thus Equation (A3.6) helps explain how energy per unit of GDP has changed due to shifts in the ratio of energy services to GDP and due to changes in end-use energy intensities. The first factor reflects that the structural evolution of economies and human activities can cause changes in demand for energy services and, therefore, consumption that enhances or offsets shifts caused by changes in energy intensities. For example, air travel measured as passenger-km has grown faster than GDP in many countries, usually more than offsetting declines in air travel intensity (energy per passenger-km), with an increase in energy use for air travel per unit of GDP as a result. On the other hand, structural changes away from energy-intensive manufacturing industries have enhanced the effect of reduced sectoral intensities in many places and thus accelerated a decline in energy per unit of GDP. Measuring the impact of these changes in the relationship between energy services and GDP is therefore crucial to understanding how the ratio of energy use to GDP changes over time.[4]

The developments in energy services per GDP indicator help to show how much of the change in energy per unit of GDP is due to factors other than changes in energy intensities. The impact of intensities at the national level is instead captured by the

4 The decomposition presented in this annex can be extended to address changes in CO_2 emissions by introducing the dimension of fuel mix. This approach can be used to assess how changes in CO_2 emissions per GDP can be decomposed into changes in supply efficiency and fuel mix, final energy fuel mix, end-use intensity effect, and ratio of energy services to GDP. The approach thus provides a framework for quantifying the relative impact each of these factors has on CO_2 emission per GDP trends. Since all of these factors, except the ratio of energy services to GDP, are represented by some of the ECO indicators presented in this publication, this decomposition approach can help weighing the impact on overall CO_2 emission trends from the relevant ECO indicators. For more details on how to decompose CO_2 emissions see: IEA, 2004 *Oil Crises and Climate Challenges: 30 Years of Energy* Use *in IEA Countries.* Paris, France: International Energy Agency.

energy intensity index at a national level (the *I* term in Equation A3.6). This is constructed through weighting the sectoral energy intensity effects (Equation A3.4) at the base-year value of energy use.

The separation between energy services effects and energy intensity effects is important from a policy perspective, since restraining energy-service demand is seldom a policy objective. This decomposition approach allows for observing the impacts of the policy elements related to energy intensity separately from changes in the structural and activity components of energy use. This helps both to determine where policies can be most effective and to monitor progress once they have been implemented.

Annex 4: Units and Conversion Factors[1]

Table A4.1: General Conversion Factors for Energy

To:	TJ	Gcal	Mtoe	MBtu	GWh
From:	Multiply by:				
Terajoule (TJ)	1	238.8	2.388×10^{-5}	947.8	0.2778
Gigacalorie (Gcal)	4.1868×10^{-3}	1	10^{-7}	3.968	1.163×10^{-3}
Million tonnes of oil equivalent (Mtoe)	4.1868×10^{4}	10^{7}	1	3.968×10^{7}	11 630
Million British thermal units (Mbtu)	1.0551×10^{-3}	0.252	2.52×10^{-8}	1	2.931×10^{-4}
Gigawatt-hour (GWh)	3.6	860	8.6×10^{-5}	3412	1

Table A4.2: Conversion Factors for Mass

To:	kg	t	lt	st	lb
From:	Multiply by:				
Kilogram (kg)	1	0.001	9.84×10^{-4}	1.102×10^{-3}	2.2046
Tonne (t)	1000	1	0.984	1.1023	2204.6
Long ton (lt)	1016	1.016	1	1.120	2240.0
Short ton (st)	907.2	0.9072	0.893	1	2000.0
Pound (lb)	0.454	4.54×10^{-4}	4.46×10^{-4}	5.0×10^{-4}	1

Table A4.3: Conversion Factors for Volume

To:	gal U.S.	gal U.K.	bbl	ft^3	l	m^3
From:	Multiply by:					
U.S. gallon (gal)	1	0.8327	0.02381	0.1337	3.785	0.0038
U.K. gallon (gal)	1.201	1	0.02859	0.1605	4.546	0.0045
Barrel (bbl)	42.0	34.97	1	5.615	159.0	0.159
Cubic foot (ft^3)	7.48	6.229	0.1781	1	28.3	0.0283
Litre (l)	0.2642	0.220	0.0063	0.0353	1	0.001
Cubic metre (m^3)	264.2	220.0	6.289	35.3147	1000.0	1

Table A4.4: Decimal Prefixes

10^{1}	deca (da)	10^{-1}	deci (d)
10^{2}	hecto (h)	10^{-2}	centi (c)
10^{3}	kilo (k)	10^{-3}	milli (m)
10^{6}	mega (M)	10^{-6}	micro (µ)
10^{9}	giga (G)	10^{-9}	nano (n)
10^{12}	tera (T)	10^{-12}	pico (p)
10^{15}	peta (P)	10^{-15}	femto (f)
10^{18}	exa (E)	10^{-18}	atto (a)

[1] Source: International Energy Agency