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ENERGY STATISTICS METHODOLOGY

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PREFACE

Official statistics must anticipate the evolution of the societies they describe and enlighten the choices of decision makers by providing them with reliable, objective and timely data on current developments in all economic and social sectors. The need for adequate and reliable supplies of energy makes energy statistics particularly important for formulating and monitoring national energy policy and to ensure that the energy market is working properly. A freely operating energy market does not naturally produce the statistical information which will ensure its transparency as no individual energy enterprise is normally willing to bear the costs of maintaining the data system. State authorities must therefore collect and publish energy market statistics.

This manual has been prepared to outline the European Statistical System in Energy Statistics and Eurostat's data requirements. It covers the following topics:

- a brief summary of Commission legislation requiring provision of energy statistics.
- the monthly and annual questionnaires used in collecting energy statistics across the Union, both on quantities and prices.
- detailed descriptions/methodologies for collecting statistics in specific fields in support of sectoral Commission policies as well as the methodology of surveys financed directly by Eurostat in order to improve the national statistical systems.
- the principles and methods used in preparing commodity and energy balances.
- an extensive description of the European system of energy statistics and in particular the data collection arrangements, the structure of the Energy Industry and the authorities responsible for the statistics collection in the Member States (EU 12).

Energy statistics need to be adapted to the evolving environment. The liberalisation of the energy markets, the close link of environment and energy and the demands on quality and timeliness arising there from, will be the determining factors in shaping the European system of energy statistics in the coming years. The present manual may serve the CEEC countries in adapting their national systems to that of the Union ; it also outlines in strengths and weaknesses of the present system which have certainly to be evaluated within the political context outlined previously.

1. STATISTICAL LEGISLATION RELATING TO ENERGY STATISTICS

1.1. OVERVIEW

In order to describe the general legal framework for Community Statistics, we have to differentiate two levels : primary law (the Treaties) and secondary law (legal acts adopted by the EU institutions as the way of implementing the Treaties).

Primary law

At the moment, there is no specific chapter or articles in the EC Treaty dealing specifically with Community Statistics ; legal bases are to be found each time in the context of the specific policies to which the expected statistical results refer (e.g. Art. 43 for agricultural statistics). So far, however, and with the exception of agricultural statistics and some other minor exceptions, the legal basis generally used for legal acts in the domain of statistics is Art. 213.

The Treaty of Amsterdam, signed in October 1997, however, envisages a new Article 213A (future Article 285 in the consolidated version of the EC Treaty) dealing specifically with Community Statistics. This new provision will therefore be applicable to all Community Statistics; it proposes a co-decision procedure (Council and European Parliament) and relates to the fundamental principles guiding Community Statistics.

Secondary law

A fundamental legal act in the domain of statistics is the framework programme for priority actions in the field of statistical information 1993-1997 (Council Decision of 22 July 1993), which will soon be replaced by the Council Decision on the Community Statistical Programme 1998-2002 (still pending at the Council).

The said draft Council Decision states that "the Community statistical programme shall define the approaches, the main fields and the objective of the actions envisaged during the period from 1998 to 2002", adding that "the Community statistical programme shall be implemented in accordance with the rules and principles laid down in Council Regulation (EC) No 322/97 on Community Statistics".

This leads to the second fundamental legal act in the domain of statistics, which is the general framework containing the rules and principles applicable to all Community Statistics; the Council Regulation on Community Statistics[1] (hereinafter, the CRCS), adopted in February 1997.

As a general overview of its main specific contents, the CRCS is firstly designed to specify the procedures which must underlie the decisions to be taken on the various statistical programmes and to divide responsibilities between national and Community authorities. Secondly, this basic Regulation affirms the need for those involved in the Community's statistical action at both national and Community level, to adhere to the same fundamental principles in order to ensure that statistics are scientifically independent, transparent, impartial, reliable, pertinent and cost-effective. Finally, the Regulation contains a minimum of rules which must be complied with in order to safeguard statistical confidentiality, as defined under a common basis at Community level, and guarantee the transmission of confidential data held by national authorities to Eurostat where these data are necessary to compile statistics for the whole of the Community.

1 OJ No L 52, of 22.02.1997, p.1

The CRCS states that the Community statistical programme shall be implemented by individual statistical actions. These actions shall be either :

a) decided on by the Council,

b) decided on by the Commission, under certain conditions,

c) decided on by means of agreement between the national authorities and the Community authority (Eurostat) within their respective spheres of competence.

It is important to stress that, according to the CRCS, the implementation of statistical actions shall come under the responsibility of national authorities unless otherwise stated in a Council legal act. If national authorities do not accomplish this task, the individual statistical actions may be carried out by the Community authority (Eurostat) with the explicit agreement of the national authority concerned.

Finally, concerning statistical confidentiality, a fundamental issue for Eurostat, account is to be taken of Chapter V of the CRCS, and Council Regulation 1588/90 on the transmission of data subject to statistical confidentiality to Eurostat[2]. In this context, it is important to stress that Article 13 of the CRCS has replaced Article 2(1) of Regulation 1588/90, meaning that statistical confidentiality will no longer be defined according to national legislation and practices, but on the basis of a common harmonised definition to be settled at Community level.

1.2. SUMMARY LEGAL REQUIREMENTS

While energy Statistics rely heavily on various legal acts related to Community Statistics and in particular activities related indirectly to data collection (nomenclatures, registers, etc), there has been a limited number of energy-specific legal acts on which the Energy Statistics system is based (Table 1.1). An overall legal act covering all Energy Statistics has not been created yet, although this matter has been considered repeatedly by the appropriate Committee. Essentially, the system functions on the basis of an agreement between the Community (Eurostat) and national authorities established over a number of years of close collaboration.

2 OJ No L 151, of 15.06.1990, p.1

TABLE 1.1. Legal References on Energy Statistics

White Paper	An energy Policy for the EU, COM (95)682 final
2393/96/ECSC	Commission Recommendation concerning coal statistics - L326, 17/12/96
58/97/EEC	Council Regulation concerning structural business statistics - L14, 17/01/97
ALTENER II	Proposal for a Council Decision concerning the promotion of RES - COM(97) 550 final
93/500/EEC – ALTENER I	Council Decision concerning the promotion of RES - L235, 18/09/93
88/349/EEC	Council recommendation concerning the development of RES – L160, 28/06/98
90/377/EEC	Council Directive concerning the transparency of gas and electricity prices for industrial consumers – L185, 17/07/90
93/389/EEC	Council Decision concerning a monitoring mechanism for CO2 emission – L167, 9/7/93
96/737/EEC	Council Decision, Programme SAVE II – L235, 24/12/96
91/565/EEC	Council Decision, Programme SAVE I – L307, 8/11/91

2. DATA COLLECTION

Introduction

The main characteristics of national energy data collection systems (coverage of supply and use, details of activities and frequency of reporting) reflect their administrative structures (centralised or federal), number and ownership of supplying companies and the past approach to data collection within the country. Wherever possible and for reasons of cost, information on the supply and use of energy is collected from energy supply companies rather than from consumers. In many countries energy suppliers are few in number and have traditionally supplied government with information on their activities. The quality of statistics describing the provenance of national supply (indigenous production, imports, own generation etc) aggregated from these sources is good but information on the total quantities sold to the different types of final consumer is very variable depending on the energy form and the number of supplying companies. In general, metered supplies of gas and electricity provide a good basis for complete coverage of national consumption broken down by consumer type whereas sales of stockable fuels (oil and coal) are less readily measured and in the hands of many more companies. Furthermore, the availability of energy consumption data from suppliers is, by definition, limited to marketed energy leaving the estimation of consumption of biomass fuels to other means.

For these reasons, and despite the considerably greater costs incurred, all countries have more or less recourse to surveys of final consumers. These surveys often collect not only actual consumption (rather than purchases) but also the stocks of fuels and the type of fuel use, for example, for electricity generation, steam for sale, process heat, etc.

The level of detail of supply and consumption activities collected by national statisticians reflects the past and present needs of the administration, major users and international organisations. Data types can be broadly divided into three groups:

Operational data	are required for regular intervention in the energy enterprise or for organising the investment and operations of the enterprise. Daily plant performance, refinery operating characteristics and plant outage are examples. The identity of the enterprise to which the figures relate is an essential part of operational data. These data are also sometimes referred to as administrative data as they support the administration of the industry's activities which are the subject of the legislation authorising state intervention.
Technological data	provide detail of fuel requirements and performance of certain technical processes or energy using equipment. For example - fuel consumption by motor cycles less than 500 cc or electricity use for electric arc furnaces. There is no interest in the individual, either legal or physical, using the process.
Contextual data	in which statistics are aggregated at a national or regional level and are used for showing the general patterns of supply and consumption within many branches of economic activity and the residential sector. These are usually provided by the energy commodity balances and associated price statistics. The degree of aggregation of the primary data usually means that neither the enterprises nor the technological processes involved can be identified from the data.

The special conditions governing the collection of operational data do not concern this manual and these data are not part of the regular data collection conducted by Eurostat. However, it should be noted that certain operational data are collected by the Commission of the European Union in support of energy policy legislation and that it is usual and essential for national energy statisticians to be involved in the provision of this information.

Chapter 3 describes the special data collection exercises undertaken by Member States which Eurostat has initiated and/or supported and which provide data falling within the technological category. However, it is the regular provision of contextual data to Eurostat and the systems which have been established for this which are the primary subjects for description and discussion within this chapter.

The style of reporting of these contextual data, differs according to the activities covered. The more general comprehensive fuel supply and use statistics exploit the conservation of mass or energy and use a balance format so that any difference between the recorded supply and all disposals becomes immediately evident. More specific enquiries relating, for example, to the iron and steel industry, mining or renewable energies are concerned with key elements of production or consumption which constitute the activities in question.

The compilation of the statistical reports to Eurostat is undertaken by the responsible statistical unit within the national administration, by a professional association or within a public body nominated by the administration. It is not recommended that a private company undertake this task, nor that of collecting the data, as its status is likely to discourage other companies from providing their data whatever may be the data protection powers given to the collecting company.

2.1. QUANTITY STATISTICS

2.1.1. Annual Statistics

The quantities of energy supplied and used are reported according to the energy type and with a frequency related to the purpose of the report. Annual data covering all energy types and their sources and uses are the most commonly provided contextual data. Eurostat and other international organisations, notably the United Nations (UN) and the International Energy Agency (IEA), have worked closely to harmonise the collection of annual data so that member countries of all three organisations are not faced with duplicated reporting requirements. A set of common questionnaires has been prepared covering coal and manufactured gases (Annex 2.1.1.), oil (Annex 2.1.2.), natural gas (Annex 2.1.3.) and electricity § heat (Annex 2.1.4.).

Eurostat also maintains a simplified annual solid fuels questionnaire (Annex 2.1.5.) required by the Treaty establishing the Coal and Steel Community in order to collect statistics within a short time after the reference year (Recommendation 2393/ECSC). It is noted that only these simplified questionnaires are sent independently to Eurostat, while the joint annual questionnaire on solid fuels is the normal reporting system for annual statistics.

The fuel types and their definitions are found within the questionnaires assembled in the annexes mentioned herein above. Generally speaking the fuel product definition reflects the marketed product and does not necessarily correspond to the characteristics of the fuel at the extraction point. Production is expressed in terms of marketable equivalent. In this manner fuel commodity balances represent homogeneous products for all sources of supply and all uses. Fuels are reported in mass or energy units, never in volume as this is pressure and/or temperature dependent and requires artificial constructs (eg refinery gain) if the integrity of balance flows during transformation is to be ensured. When mass units are used the net calorific value (lower heating value) should be provided so that energy balances can be prepared.

The questionnaires are reviewed annually by the Intersecretariat Working Group for Energy Statistics (IWG(En)) which comprises the Heads of Energy Statistics in the UN Economic Commission for Europe (UNECE), IEA and Eurostat. UN Statistical Office in New York is also regularly consulted. Any modification of the joint questionnaires are discussed within the Energy Statistics Committee (Eurostat), too.The IEA acts as Secretariat for the IWG(En) and, during the month of June each year, issues questionnaires, requesting data for the most recent calendar year, to Member States and member countries of all three organisations. Completed questionnaires are usually required to be returned to the IEA and Eurostat before 31 August.

2.1.2. Monthly Statistics

Monthly reporting of quantity data is limited to coal (Annex 2.2.1.), oil and natural gas (Annex 2.2.2.) and electricity (Annex 2.2.3.) supplies.

Of these fuels only oil is covered extensively. The past disruptions in oil supply have led Member States and other industrialised countries to act in concert, create response mechanisms and monitor frequently oil supplies and stocks. Assessment of oil supplies at times when they are causing concern requires data not only for the present and past few months but for the recent past so that any possible shortfall in supplies can be compared with recent trends and seasonal movements. The Monthly Oil and Gas joint questionnaire provides the necessary time series for both Oil and Natural Gas.

Eurostat has a simplified questionnaire for reporting short-term coal statistics. Only three short monthly questionnaires are required covering the supply and main uses of hard coal, lignite, peat, coke and patent fuels. The origins of hard coal imports are also requested (Recommendation 2393/96/ECSC).

Electricity is covered by a two page questionnaire seeking figures for gross and net production from the different categories of power stations, including pumped storage stations.Inland consumption information is inferred from net production, external trade and consumption at pumped storage stations. Figures for fuel consumption at public thermal stations and stock levels are also collected.

Eurostat maintains a database of nuclear power reactor operating statistics based upon a single page questionnaire summarising key output figures and plant outages coded by main causes (Annex 2.2.4.). This reporting system is well defined and has been operating for many years. It contributes useful information on the contribution and performance of the nuclear power generating sector. Eurostat transmits collected information to the International Atomic Energy Authority (IAEA).

2.2. PRICE STATISTICS

The preface to this manual refers to the importance of statistics in ensuring that energy markets function transparently. Nowhere is this more important than in the realm of energy commodity prices.

By collecting and publishing price statistics, the aim of the Commission is to:

- increase the capacity of users to choose between energy sources and different suppliers
- reinforce conditions which ensure that competition flourishes.
- help to obviate discrimination against users
- ensure similar degrees of transparency for different types of energy sources and across European Union countries and regions
- be sufficiently informed to decide, as necessary, on appropriate action or proposals in the light of the situation of the internal energy market.

To help achieve these aims two systems of price data information have been introduced covering,

a) Gas and electricity prices and taxes, including information on charging structures.

b) Price information for petroleum products and hard coal.

The precise content of these systems and forms of reporting, as well as the manner in which the information is published are described in Annex 2.3.

2.3. INFRASTRUCTURE

Information on the existing energy supply infrastructure is of importance for informed discussion of supply security and contingency planning as well as assessing security implications of future supply arrangements.

Basic infrastructure information is requested in two of the annual questionnaires described above. The natural gas questionnaire contains tables to collect information on lengths of natural gas pipelines grouped by diameter classes, capacity of underground storage, maximum gas in storage and maximum output capacity. Similar data are sought for the storage of liquefied natural gas. The electricity and heat questionnaire requests data on the net maximum electrical capacity by detailed plant type and by public and autoproducer category.

Eurostat also collects systematically, from national specialist publications, other infrastructure information relating to production and transmission of gas and electricity.

2.4. SOCIAL STATISTICS

Limited information on employment and its structure in the Coal industry is requested in the annual coal questionnaires ; relevant information has been included in the appropriate annexes.

3. SPECIAL DATA EXERCISES

The differences in uniformity of data collection, both in detail and scope, which exist across Member States (see chapter 6) weaken the quality of analysis undertaken by the Commission and its capacity to monitor the effects of past policies and predict the consequences of new ones. In response to this general concern the Energy Unit of Eurostat has, in its area, encouraged the development of new or improved data collection systems on a common basis. The most notable of these to date is the household energy consumption survey, the collection of statistics of renewable energies and the collection of statistics on combined generation of power and heat (CHP). However, other studies are also conducted on a regular or occasional basis (e.g. Input/Output tables). Recently, a project was initiated to survey the energy consumption in the services sector.

In some cases, Eurostat has contributed financially to the initial costs of setting up data collection sytems as well as arranging the planning and design meetings. However, Eurostat does not provide continuing financial support. In other cases, it has played the coordinating role and has brought the various experts together to settle upon a common approach and/or definitions.

3.1. SERVICES SECTOR

Energy consumption in services is the weakest part of energy statistics in most Member States since appropriate direct surveying of energy consumption is carried out only in one Member State. Due to the high level of cost for such a direct survey, Eurostat has financed a project-study to develop a simplified approach allowing the relevant statistics to be estimated on the basis of economic statistics available in the Member States and unit consumption to be determined from small samples. The method is outlined in Annex 3.1. and it has been the basis of work currently implemented in a few Member States to collect relevant statistics. In principle, a survey should have been carried out in all Member States by the year 2000.

3.2. HOUSEHOLDS

Improving the quality of data relating to household energy use is an important part of Eurostat's programme of data exercises. Household energy consumption (excluding use of fuels for transport) is a substantial element in national energy consumption but because it comprises so many relatively small purchases, total household consumption is often taken as the residual after industrial, commercial and transport consumption have been accounted for. As a result, the quality of data for stockable fuels is generally poor and figures for locally gathered and/or traded fuels, notably firewood, are difficult to obtain.

Uncertainty in the data translates directly into an imperfect grasp of the patterns of household fuel use and how it is related to income, living patterns and housing standards. Such information is invaluable for the formulation of social, housing, environment and energy policies.

In order to improve data in this sector, Eurostat has encouraged Member States to conduct surveys and assemble data from household surveys and specialised databases on a regular, but not annual, basis. The results of the survey for 1988 have been described in *"Energy Consumption in Households"*, published in 1993 (ISBN 92-826-6543-7). This exercise was repeated with reference year 1996 and the results of this survey are under preparation.

The continuing programme of household survey work has been extended recently to include applicant countries from Central and Eastern Europe. The household energy consumption project has been financed by the EC from its PHARE Energy Programme funds and is due to be completed at the end of 1997 covering consumption in 1996.

Annex 3.2. gives the Work Programme, including the definitions, used in implementing these surveys.

3.3. RENEWABLE ENERGY SOURCES

Council Recommendation 88/349/EEC proposed that Member States, in cooperation with Eurostat, establish a system for the collection of statistics on renewable energy sources (RES). The statistics would allow RES penetration to be monitored and their contribution to the diversification of supplies assessed. The Commission created a RES statistics working group comprising officials from Member States which met on three occasions over the period 1989-94. During these meetings methodological issues were discussed together with national experiences in the collection of RES statistics. The commercially mature RES technologies and their major fields of application were defined. For each application a set of statistics were determined which allow assessment of the policy objectives described above.

The actual means adopted by Member States for the collection of the RES statistics is left to their discretion as it depends strongly on existing national systems for energy statistics and the development of RES in Member States.

Annex 3.3. contains the proposal for the statistics to be collected and the main technological parameters needed to incorporate the contribution of RES in energy balances as well as monitor their penetration and use within the energy economy.

3.4. CHP SURVEYS

Combined Heat and Power generation is an efficient method for generating electricity both for energy saving purposes and emissions reduction. Eurostat finances the collection of relevant statistics under the SAVE programme. Annex 3.4. outlines the methodology, including definitions in collecting relevant statistics.

Statistics were collected for the first time in 1994 (reference year) and have already been published. The survey is carried out on an annual basis since 1996 in order to improve the quality of statistics (coverage, harmonisation) as well as strengthen further the collection and establish it as part of the regular data collection system.

3.5. INPUT/OUTPUT TABLES

An "input/output" table for the flows of energy in an economy is a specialised version, adapted to energy, of the similar, "whole-economy", table prepared from national accounts statistics. The energy table follows general lines and principles of the national accounts table although some adjustments are required to present appropriately the energy flows. A fuller description of the construction and structure of input/output tables for energy is given in Annex 3.5..

Specialised IO tables for energy, consistent with the energy balance sheets, are useful instruments for analysis and forecasts in this sector as they contribute to a number of different studies.

- ***Interdependence of energy branches***

Energy IO tables give detailed information about the dependencies and interdependencies between the energy and other branches.

- ***Physical energy content of commodities***

From energy IO tables, it is possible to calculate the total energy required to produce the output of each branch but also the indirect energy needs. That is, the energy used to make the goods and services that each branch purchases from other branches, and the energy used to make the purchases of that branch, *ad infinitum*. By taking into account both direct and indirect energy use it is possible to identify those sectors of the economy which use the greatest quantity of energy per ECU of output (energy intensity).

- ***Energy costs of commodities***

Again with the help of IO analysis the total (direct and indirect) energy costs can be determined. This allows estimation of the effects of sudden increases or decreases of energy prices or taxes.

- ***Environmental themes***

Energy IO tables can be usefully extended from energy intensities to carbon intensities. The analysis can be developed to allow a comparison of the total energy costs or total CO_2 emissions of substitute goods or services. It can also be extended to other pollutants.

- ***Simulation of alternative energy strategies or energy forecasting***

Energy IO tables can be utilised for energy simulation and energy forecasting. In particular, possible effects on the supply and demand of energy sources which result from a change of final demand technology and international trade can be measured.

4. CLASSIFICATIONS, NOMENCLATURES

Energy statistics is an integral part of the European system of statistics. Therefore, they rely heavily on classificationsand nomenclatures developed in other fields while classificationsproper to the Energy statistics are fully harmonised with the classifications used in other fields of the European system of statistics. This harmonisation allows :

- cross-sectoral comparability of statistics and estimation of indicators (e.g. energy consumption per value added by an industrial sector)
- direct exploitation of statistics made available by related surveys (e.g. external trade).

The classifications and nomenclatures used for energy statistics are mentioned explicitly in the joint questionnaires (annex 2.1.). In summary, the following general or energy-specific nomenclatures are used.

4.1. Product classification

The existing Community's survey system of industrial production (Council Regulation 3924/91, L374, 31.12.1991) was recently completed to include the energy products of commercial value. The relevant list (Annex 4.1) has been made compatible with the nomenclature of external trade statistics (Council Regulation 2086/97, L312, 14/11/1997), so that external trade statistics necessary for energy may be directly obtained from the relevant surveys on external trade.

4.2. Classification of economic activities

The classification of the economic activities both in carrying out the surveys and in presenting the results (Energy Balance Sheets) is in accordance to NACE Rev1, the statistical classification of economic activities in the European Community (Council Regulation 3037/90, L293, 24.10.1993). It should be noted, however, that in presenting energy statistics important deviations appear which may pose problems when the energy statistics are compared with related ones coming from the national accounts. The relevant deviations are listed below:

- Electricity generation from autoproducers is presented separately from the sector where it takes place,
- Energy consumption for Transport is also separated from the actual sector where it takes place,
- The Energy Industry both as a consumer and as a transformer of energy has been separated from the rest of the industry.

The close link between energy and environment statistics has recently put pressure on to revise these conventions, conventions initially conceived because of the primary use of energy statistics i.e.; in shaping or evaluating energy policies.

5. COMMODITY AND ENERGY BALANCES

Introduction

This chapter describes the systems of basic statistics and energy balances published by international organisations so that users of the information can understand the framework of definitions supporting the data collection process and the assumptions and conventions used to present the statistics. The definitions and conventions are loosely referred to as the methodology Energy statistics are widely and increasingly used to support modelling and planning activities in many fields. These include studies of energy supply investments, preparations for the privatisation of energy companies, energy security, energy efficiency and the environmental effects of energy supply and use. The energy statistician assists those engaged in this work by assembling data, classifying fuels and activities and providing advice on the conceptual basis of the data, its strengths and limitations. The statistician must also present the data in a natural and instructive manner. The format used should reflect the normal flow of energy from supply to use but also reveal the underlying formal similarities of the processes used and the dependencies of the supply of one form of energy on another.

Energy statistics will be constantly evolving under the stimulus provided by the interaction between statistician and users. In particular, it will be evident from the contents of this work that, in some respects, the form of energy balances reflects conventions developed from past demands for data arising from a context of energy supply and use in market economies. This context differs in several respects from the one prevailing today and from that found in the countries of the former Soviet Union and central and eastern Europe. Today, gas and electricity supplies in particular, are becoming more diversified through the effects of privatisation and the fostering of competition. Industrial and commercial consumers are entering the market to supply energy commodities as well as use them. The types of generation process and energy commodities used often differ from those employed by the large public utilities and the activities may be spread over numerous small sites. Equally, the need for a truly international methodology for the construction of commodity and energy balances means that the concepts and methods used by the economies in transition for the accounting of the cogeneration of electricity and heat, district heating and the final consumption of energy commodities are likely to influence the conventions used in future revisions to the international methodology.

5.1. FUELS AND ENERGY

There appears to be no commonly used noun in the English language describing, collectively, the fuels, electricity and heat as sources of energy. A number of somewhat colourless terms are used by energy statisticians such as, *energy carriers, energy commodities, energy vectors, energy ware or energy forms.* Rather than add to this vocabulary *energy commodities* will be used here. *Fuels* comprise *combustible fuels* which are materials containing carbon and/or hydrogen capable of ignition and combustion, and *nuclear fuels.* Combustible fuels include commodities which are not normally purchased to be burned such as solvents or lubricants.

Energy commodities are either drawn directly from natural resources (and are termed *primary*) or are manufactured from primary energy commodities. All energy commodities which are not primary are termed *secondary* although some forms of energy may be produced from secondary energy commodities. The generation of electricity by burning fuel oil produced from crude oil is an example.

Primary energy commodities may also be divided between fuels of fossil origin and renewable energies. Fossil fuels are taken from natural resources which were formed in the geological past. By extension, the term fossil is applied to any secondary fuel manufactured from a fossil fuel. Apart from geothermal energy, renewable energy forms are drawn directly or indirectly from current or recent flows of the constantly available solar and gravitational energy.

The large majority of the world's energy consumption is obtained from the heat of combustion of fossil fuels with heat from biomass fuels making a smaller but important contribution. In fact, with only marginal exceptions, fossil fuels provide their energy only in the form of heat whereas the energy supplied by renewable energy commodities may be thermal in origin (biofuels, geothermal, solar etc) or non-thermal. Apart from the direct production of electricity by photo-voltaic cells, other forms of non-thermal energy are mechanical in nature derived from water or air in motion and converted into electricity for transport to the consumer. Despite the conversion of these sources into electricity it is the electricity which is considered the primary energy commodity. The choice by energy statisticians of the primary energy commodities for renewable and nuclear energy will be discussed later.

5.2. BALANCE STRUCTURES

The presentation of energy statistics in the form of balances between the supply and use of the energy commodities provides both order to and control of the available data. Energy data are expressed in terms of three different physical quantities, volume, mass and energy content. The conservation of mass and energy permits construction of balances expressed in terms of these quantities. Balances for some commodities expressed in terms of volume are possible provided that the commodity is reasonably homogeneous and, for fluids, all data relate to the same temperature and/or pressure. The use of volume does, however, require artificial constructs when the balance between the inputs to and outputs from some transformation processes needs to be demonstrated. The most notable example is the need for a refinery gain term to balance the volume of petroleum products manufactured against the volume of primary oils used to produce them.

The *commodity* balance, in which the total supply of a commodity is described in terms of its disposition over many different uses, is a fundamental tool for the energy statistician. With it the completeness of the data gathering activity may be demonstrated by showing that the sum of the various disposals of the commodity equals the supply. Equally, through the juxtaposition and rearrangement of commodity balances and their expression in a common energy unit the contributions and interrelationships of the fuels within the economy may be shown. This is the *energy* balance.

The unification of the commodity balances through the use of a common energy unit and the presentation in an energy balance is a simplification of the complexity of fuel use and energy commodities. The energy balance is simplistic in that it presents fuel quantities in terms of their physical energy content without taking account of the limitations on the substitutability of fuels imposed by their form, the technicalities of combustion processes or of the more fundamental asymmetry between heat and electrical energy. Nearly all electrical energy delivered may be converted into useful work but the second law of thermodynamics expresses severe limitations on the extent to which a quantity of heat can be converted into useful work or electricity.

Provided, however, that users bear these points in mind the simplicity and constraints of the energy balance are also its strengths. Each quantity within it represents its physical energy content and conversion between one energy commodity and another is accurately represented. As a result, the balance provides a starting point for investigations of the effects of changes in energy supply and use within an economy.

5.3. COMMODITIY BALANCES

The construction of energy commodity balances requires identifying and quantifying their main elements of supply and use, categorising and grouping activities in the extraction of primary and production of secondary commodities and the choice of natural physical units to characterise the quantities involved.

The major division of the balance is between supply and use of the commodity. The supply part of a balance shows the sources of national supply and disposals to foreign users. (See box)

UNITED KINGDOM 1994	Gas/diesel oil 1000t
Primary Production	-
Recovered Products	-
Imports	1 171
Stock Changes	48
Exports	5 904
Bunkers	1 199
Gross Inland Consumption	-5 884
Transformation Input	69
Public thermal power stations	56
Autoprod. thermal power stations	10
Nuclear power stations	-
Patent fuel & briquetting plants	-
Coke Oven plants	-
Blast Furnace plants	-
Gas Works	3
Refineries	-
District Heating plants	-
Transformation Output	27 152
Public thermal power stations	-
Autoprod. thermal power stations	-
Nuclear power stations	-
Patent fuel & briquetting plants	-
Coke Oven plants	-
Blast Furnace plants	-
Gas Works	-
Refineries	27 152
District Heating plants	-
Exchanges, transfers and returns	0
Interproduct transfers	-
Products transferred	-
Returns from petrochemical industry	-
Consumption of the energy branch	16
Distribution losses	-
Available for final consumption	21 183
Final non-energy consumption	659
Chemical Industry	659
Other Sectors	-
Final energy consumption	20 337
Industry	2 286
Iron & Steel industry	136
Non-ferrous metals industry	23
Chemical industry	150
Glass, pottery & building materials	154
Ore extraction industry	302
Food, drink and tobacco industry	150
Textile, leather & clothing industry	44
Paper and printing industry	34
Engineering and other metal industry	312
Other industries	981
Transport	14 473
Railways	588
Road transport	12 914
Air transport	
Inland navigation	971
Households, commerce, public. adminstr.	3 578
Households	244
Agriculture	640
Statistical difference	187

Commodity uses are categorised by the primary economic activity of the user and grouped according to whether the fuel delivered is used for production of a secondary energy commodity (transformation activities), to support energy industries' activities other than transformation (energy sector own use) or for final consumption by other types of users.

Units of mass or energy are chosen to present the commodity balance in familiar terms taken from everyday use. Where practice differs around the world international organisations adopt a unit taking into account the generality of its use and the uniformity of its definition.

The parts of the balance will now be considered in more detail.

5.3.1 Supply

With the exception of the commodities mentioned in the following paragraph, *production* includes all extraction (excluding recovered or recycled products) of primary energy commodities expressed in marketable terms. The energy commodity may not be in a marketable condition at the point where production is measured but the quantity reported as produced should be the marketable content. This ensures that the balance describes a recognisable product consistently reported in a common unit. What is "marketable" is determined by consumers but where energy commodities are traded internationally there has been an approximation of product specifications so that commodities can be compared and valued more easily. Production includes quantities subsequently consumed by the producer but, for the case of natural gas, production excludes gas vented, flared or reinjected into wells.

Production of biofuels is taken to be the sum of all the quantities combusted or used. This is because actual annual production, for commodities such as wood or ethyl alcohol, serves both energy and non-energy uses and sometimes the latter will predominate. That part of production serving energy needs, inferred from consumption, is included in the balance. The quantities combusted are usually, but not always, expressed in energy units and measured at the points of combustion. For example quantities of straw or landfill gas burned for generating electricity are normally available in energy units. However, residential consumption of wood is usually estimated from volumes delivered using average calorific values and moisture contents.

Indigenous (primary) heat is produced from geothermal sources, active and passive solar heat capture, extraction of ambient heat by heat pumps and from nuclear reactors.

Geothermal heat supply comprises contributions from reservoirs exploited by main suppliers created for that purpose and the capture by individuals or private enterprises (eg horticultural undertakings). Only the former is readily measured and recorded but in countries where geothermal energy is important estimates of amounts extracted by individual enterprises are made. For countries where geothermal steam is used uniquely for electricity production and detailed plant operating statistics are not available estimates of the geothermal heat used may be made from the electricity produced assuming an average thermal efficiency of the order of fourteen percent.

Quantities of solar heat actively captured are reported directly by significant producers based on the heat output of the collectors. Energy obtained by small flat plate collectors can be estimated approximately when the total area of the installed collector surface is known. Currently, no attempt is made to collect data for the contribution made to national energy requirements by passive solar design and practices.

A number of industrialised countries use heat generated in nuclear reactors for heating purposes as well as generating electricity. These alternative uses make heat rather than electricity the natural choice as the primary energy emerging from reactors. Each month Member States of the European Union report heat output from their reactors but other OECD countries do not so their reactors' heat output must be inferred from the electricity produced. The average thermal generating efficiency for nuclear stations observed in Member States (33 percent) is used by the IEA for this purpose in other countries.

Primary electricity is produced by hydro power plants, wind turbines, tidal barrages and photovoltaic solar panels. Primary production of hydro electricity comprises generation from natural water flow plants. Pumped storage plants are not considered as producing primary energy.

The selection of heat rather than electricity as the primary energy commodity available from nuclear reactors is an example of the criterion used by energy statisticians to decide between competing candidates for the primary energy form. The choice of the point in the chain of supply of non-fossil, primary energy sources at which they may be considered available for use determines the primary energy source used in the balances. In general the choice is guided by the pragmatic desire to go no further "upstream" than is needed to account for all disposals. The case for nuclear heat has been given above. The primary energy form for hydro electricity is taken to be the gross electricity generated. Energy further "upstream", such as the kinetic energy of the falling water would be a viable alternative if the part not absorbed by the turbine were used for other identifiable purposes. At present this is not the case.

Similarly, electricity produced from aerogenerators, tidal or wave generators and photovoltaic panels is taken to be the primary energy form from these energy sources.

Note that the choice of primary energy commodity and how it should be expressed as production in the energy balance are separate decisions which will be discussed in the section on energy balances.

The choice of primary energy commodity can have consequences for the construction of indicators of energy supply dependence. For example, in the case of nuclear energy, if the energy content of the nuclear fuel were chosen to be the primary energy commodity than the heat production, dependence of most countries with nuclear power stations would increase as they import the greater part of their nuclear fuel supplies.

The definition of production used by Eurostat and described above differs from that employed by the IEA for its *commodity* balances. IEA includes both primary and secondary energy commodity production within the production row of its commodity balances but only primary energy in the production row of its *energy* balances.

Quantities of recovered or recycled products re-entering supply are reported under *Recovered Products*.

Figures for *imports and exports* of energy commodities relate to quantities crossing national borders and exclude quantities in transit or in free trade areas awaiting onward shipment to a third country. However, as the identification of quantities of electricity and gas in transit is difficult without recourse to contract information it is customary to report their gross cross-border flows.

International Marine Bunkers describes the deliveries of fuels (mostly oils) to be consumed on ships of any flag embarking on voyages to other countries. The deliveries are considered equivalent to exports and not part of inland navigation consumption. Transport on inland or coastal waters, or unbroken transport voyages, whatever their length, which start and end in the same country are classified as inland navigation. Oil consumed by deep sea fishing vessels in international waters is classified under fishing. These distinctions are easier to put on paper than to make in practice and it is certain that figures reported for international marine bunkers include some quantities belonging to the two other categories.

There is an ongoing debate as to whether aviation fuels supplied to aircraft making international flights can be included with international marine bunkers thereby changing the category to international bunkers. The balances prepared by the U.N. Statistical Division in New York already places the two types of consumption together in the supply matrix. Consumption of fuels for international flights is directly analogous to that for international sea voyages and there seems little room for disagreement over the principle. However, other international organisations have not adopted the practice as few countries are yet able to supply reliable data for the international component of aviation fuel deliveries. In part because oil delivery statistics are usually based upon oil company reporting systems which stop with the record of quantities delivered to the airports, but also because, even when quantities delivered to the aircraft are known, aircraft in large countries may make flights combining domestic with international journeys. To further complicate the matter, some countries treat all deliveries to the national airline as domestic fuel use irrespective of the destinations served.

Stock changes represent the additions and withdrawals from stocks held by producers, transformation industries, and large consumers where national law obliges them to hold stocks for energy supply security reasons. Quantities of fuels held in free trade areas and awaiting onward shipment to a third country are not included in national stocks.

5.3.2 Transformation

Transformation Input
Public thermal power stations
Autoprod. thermal power stations
Nuclear power stations
Patent fuel & briquetting plants
Coke Oven plants
Blast Furnace plants
Gas Works
Refineries
District Heating plants
Transformation Output
Public thermal power stations
Autoprod. thermal power stations
Nuclear power stations
Patent fuel & briquetting plants
Coke Oven plants
Blast Furnace plants
Gas Works
Refineries
District Heating plants

Transformation converts a primary energy commodity, by physical and/or chemical means, into a secondary form which is better suited than the primary to the uses for which the secondary form is intended. Quantities of fuels used and secondary commodities produced are shown in the transformation sector of the balance. The distinguishing features of transformation activities are that a significant part of the calorific content of the primary fuel is transferred to the secondary commodity and that the transformation activity usually takes place in locations which are separate from the consumption of the secondary energy produced. Both features justify the assembly of transformation activities within their own matrix and the creation of energy balances revealing the energy transfers between commodities and their use in the final consuming sectors.

Quantities shown as inputs to transformation activities are those entering the transformation process. The outputs are "gross", covering all product sales and any use by the producer. Purchase and use of commodities by transformation industries for own consumption (eg electricity) and not transformation falls under "Consumption of the Energy Branch" (Section 5.3.4).

The Eurostat commodity balance records quantities delivered into each of the transformation activities (transformation input) identified in the balance and the quantities produced (transformation output). (See box). However, the secondary energy produced from the inputs is shown under transformation output within the commodity's own balance. It is very rare for there to be both input and output of an identical commodity from a transformation activity. The IEA balance and some national balances use a single transformation matrix representing only the quantities input into transformation. Secondary production appears within the production row of the corresponding balance. Production within these commodity balances therefore covers both primary and secondary production unlike their energy balances where production is limited to primary (indigenous) production. Although a single, input-only transformation matrix leads to dissimilar structures for commodity and energy balances (IEA case) it does have the advantage of producing a more compact balance format.

5.3.2.1. Electricity and Heat

The nature of the activities and types of enterprises in the transformation sector which generate electricity and heat are quite precisely defined. Firstly the producers are classified according to the primary purpose of production into Public and Autoproducer undertakings.

Public supply undertakings generate electricity and/or heat for sale to third parties as their primary activity. The undertakings may be publicly or privately owned. The electricity or heat sold need not be distributed through a grid or pipe network but may be supplied to the third party through a local link.

Autoproducer undertakings generate electricity and/or heat wholly or partly for their own use as an activity which supports their primary activity. They may be publicly or privately owned. As the financial benefits of generating electricity for sale in certain countries become more attractive to autoproducers they are building additional generating plant for public supply.

In addition to the classification of producer and to avoid ambiguities in data collection the types of plant are divided into three groups (not shown in the box above but explicitly identifed in the joint questionnaires).

Electricity plants are those designed to produce electricity only.

Combined Heat and Power (CHP) refers to a plant which is designed to produce both heat and electricity. If one or more units of a plant is a CHP unit then the whole plant is designated a CHP plant.

*District Heating (*heat only) plants, in addition to conventional combustion plants, include heat pumps, electric boilers and plants which add heat to geothermal hot water or steam.

The choice of the plant as the basis for reporting electricity and heat generation is largely determined by the greater availability of statistics on plant performance. However, the definition of CHP plants is unsatisfactory to the extent that it groups together plants in which all units are CHP units with those containing a mixture of CHP and electricity and/or heat only units. In order to obtain better data, countries which have statistics of heat and power generation on a unit basis are encouraged to read the definitions given in the questionnaires and report in terms of unit rather than plant. The survey of Eurostat on CHP plants collects data on a unit basis.

The separate statistics collected by the questionnaires for fuel use and electricity generation by *Public* and *Autoproducer* undertakings and heat output in District Heating plants are aggregated to provide the figures for inclusion in the transformation sector under the headings shown above.

Total electricity generation comprises all production from public and autogeneration plants. Electricity generated within industry or commercial enterprises and used on site is included. In this manner total fuel use for electricity generation is identified and, through the electricity balance, electricity consumption by industry branch is known. The identification of all electricity generation within the transformation sector will become increasingly important as diversification in electricity supply increases and autogeneration meets a larger part of public and own supply. If, in addition to generation by public plants, only electricity sold by autogenerators were included in the transformation sector then the electricity consumption by industry branches would be understated by the amount of their own production.

Heat generation by autoproducers is, however, treated differently. Total heat production represents only heat produced *for sale* whether by public or autogenerators. Heat produced for own consumption is not included.

This convention complicates reporting electricity and heat production from autogenerators' CHP plant and the corresponding fuel use. Because only part of the heat produced (the quantity sold) is included in national heat production figure, only part of the fuel used for heat produced at the plant (but all the fuel use for electricity) will be reported under the CHP heading in the transformation matrix. The remaining consumption of fuel by the plant, corresponding to the use of heat on site, will be included in the consumption by the branch of industry in which the CHP activity is taking place. The division of fuel use between the heat for sale and that used locally requires a prior division of total fuel use between the electricity and heat produced by the plant. Unfortunately, this may be made in a number of different ways and no standard method has been adopted by experts in heat and power generation. The reporting instructions accompanying the annual questionnaires recommend that local conventions are used to provide estimates of the fuel use for heat production in CHP plants. In the absence of such conventions a default estimating procedure, taken from UNIPEDE sources, is offered in the questionnaire.

Geothermal heat supply may be direct to consuming sectors (including electricity generation) or may be delivered to plants where the enthalpy of the hot water or steam is "topped up" by burning conventional fuels. In this case, geothermal energy is shown as entering heat plants and the associated figure for heat production reflects the geothermal heat input and conventional fuels burned to enhance steam quality.

The contribution that heat pumps make to the energy supply of most countries is minimal but there are a few, mostly Nordic countries, which use them widely and for which a statistical methodology is required. The methodology recently adopted assumes an idealised heat pump which extracts heat from low temperature surroundings and delivers it together with the heat equivalent of the electricity driving the pump to higher temperature surroundings. Collection of statistics of heat production by heat pumps and the electricity required to drive them presents few problems in those countries where they are actively used. The main difficulty is identifying and quantifying the source of the heat extracted by the heat pump in order to avoid double counting. Heat pumps may take heat from ambient fluids (air or sea water for example) or from waste heat flows originating from the use of energy commodities already appearing in the balances. Estimating the share of heat production derived from each type of source relies heavily on local knowledge.

5.3.2.2. Manufactured solid fuels

This generic title covers transformation activities in Gas Works, Coke Ovens, Blast Furnaces, Oxygen Steel Furnaces and Patent Fuel plants (low temperature carbonisation products, coal and lignite briquettes etc.).

The methodology for the reporting and presenting fuels used in Coke Ovens is simple. It applies equally to coke ovens at gas works, where town gas and gas coke are made, and at coke ovens in the iron and steel industry. The quantities of each type of fuel used are reported and shown as inputs within the transformation sector and the coke, gases, oils and tars leaving the oven are reported as gross production within their respective commodity balances. Use of gas for heating coke ovens, for example, will be shown as "Consumption of the Energy Branch" within the gas balance.

Collecting and presenting similar data for Blast Furnaces is more complicated. Blast furnaces use the carbon in their inputs for transformation (into blast furnace gas), as fuel for heat production and as one of the sources of carbon dissolved in the pig iron made from the iron ore. (The other is the limestone flux charged with coke and pig iron into the blast furnace.) Until recently energy statisticians did not try to report in full detail the actual physical inputs to and outputs from blast furnaces. It was assumed that the only fuel carbon entering the blast furnace was coke oven coke and the only energy commodity leaving the furnace was blast furnace gas. The quantity of coke transformed was calculated from the blast furnace gas produced by assuming that the entire calorific content of the coke transformed appeared in the blast furnace gas produced. The process was therefore assumed to be 100 percent efficient. Any coke used in excess of the imputed quantity was shown as consumption by the iron and steel industry.

Over recent years, however, the amounts of pulverised coal injected into blast furnaces to economise on coke use, has increased considerably. Equally, it has become evident that other fuels are used widely for the same purpose. These may be fuel oil, natural gas or recovered, used lubricants. The coal industry has considerable interest in monitoring the use of these fuels for its market analysis and environmental analysts need better descriptions of blast furnace activity for the estimation of the associated emissions.

Consequently, the questionnaires now request that all fuels entering blast furnaces be shown as transformation inputs and, by using a model of the blast furnace process, the fuel quantities may be divided between transformation and combustion. The combustion component is presented as final consumption by the Iron and Steel industry.

Blast furnaces are frequently run in tandem with *oxygen steel furnaces* which convert the pig iron to steel. The oxygen steel furnace is subsumed into the blast furnace model for energy balance purposes. Conversion of pig iron to steel involves blowing oxygen over the furnace contents maintained at a high temperature. During the process much of the carbon contained in the pig iron is partly oxidised to carbon monoxide and leaves the furnace as oxygen steel furnace gas, also known as LD or converter gas. As almost all of the carbon contained in the pig iron is oxidised the blast furnace model is simplified by assuming that no part of the fuels input is attributed to non-energy use.

The fuel inputs to *Patent Fuel and Briquetting* plants include, in addition to the main fuel components, any combustible materials used as binders for briquette or other fuel aggregates.

5.3.2.3. Refineries

Quantities shown as entering refineries represent the requirements for the manufacture of finished petroleum products commonly traded and a number of specialist chemicals and feedstock derived from oils input. The gross production covers customers' requirements and the refineries own fuel needs. Oils used by refineries comprise both primary crude oils and natural gas liquids and finished, semi-finished or used oils for blending or further processing. Refineries and Petrochemical companies often work in extremely close proximity and, as both are processing hydrocarbons, this can lead to unreported flows between the two.

5.3.3. Exchanges, transfers and returns

There are three activities included here which need explanation.

Interproduct transfers cover movements between products which represent

(a) real reclassification of products due to changes in quality and therefore specification. For example, aviation turbine fuel which has deteriorated or has been spoiled is reclassified as heating kerosene.

And

(b) the aggregation of a commodity supplied from different sources into a single balance for disposal. For example, electricity produced from non-thermal sources, hydro, wind, tide etc is transferred from these commodity balances, which concern only supply, to the electricity balance.

Products transferred describes reclassification of oil products which are imported as finished petroleum products for use within refineries as feedstock or blending products. The quantities imported are transferred from their incoming balance under this category into the refinery feedstock balance. Under ideal circumstances the sum of all quantities transferred to the refinery feedstock balance will be equal to the receipts shown in that balance.

Returns from Petrochemical

Certain petroleum products are manufactured by the petrochemical industry as by-products of ethylene production from naphtha and other feedstock. The by-products are usually returned to refineries (backflows) for further treatment before emerging as finished petroleum products meeting market specifications. Quantities shown under the Returns from Petrochemical heading represent a part of the products supplied to the industry as hydrocarbon feedstock. The remaining amounts delivered are shown in the final non-energy consumption (Chemical and Petrochemical branch of the industry in the case of IEA.) where they are made into non-energy products. The sum of the products in the returns from Petrochemical heading is equal to the total quantity of backflows produced.

5.3.4. Consumption of the energy branch

This part of the balance shows the quantities of energy commodities consumed within the energy enterprises in the sense that they disappear from the account rather than appear as another energy commodity. It is customary to distinguish final consumption within the energy sector from other parts of industrial activity although, by its nature, it is part of final consumption and industry sector. The energy consumed by the enterprise may be purchased directly for consumption or be taken from the secondary energy commodities it produces.

5.3.5. Final consumption

The quantity of a commodity available for final use is divided its use for non-energy and energy purposes.

5.3.5.1. Final Non-energy Consumption

Fossil fuels may be used as raw materials for the manufacture of non-fuel products. For example, naphtha (light distillate feedstock) is used for the manufacture of ethylene which, in turn, is used to produce plastics, or natural gas may be used for the manufacture of ammonia. The use of the hydrocarbon (or carbon) content of fuels as raw material is an activity which is almost entirely confined to the refining and petrochemical industries where some of the manufacturing processes or stages of processes involve oxidation of feedstock carbon and are exothermic thereby contributing to the heat required by the process or to steam raising in the plant. It is rare, however, that statistics of the energy contribution from feedstock use are available.

Equally fuels, such as lubricating oils, solvents or bitumen, may be used for their physical properties.

Eurostat reports both types of non-energy fuel use in the appropriate sector (Chemical industry or Other) under Final Non-Energy Consumption. IEA leaves figures for the raw material use of fuels by the petrochemical industry in energy consumption under Chemical and Petrochemical Industry. Other forms of non-energy fuel use are explicitly identified in the "Non-Energy Use" sector.

Note that part of the petroleum products delivered to the chemical industry and which are returned as by-products to refineries are not included in the quantities shown here. These "backflows" quantities are reported under "Exchanges, transfers and returns".

5.3.5.2. Final Energy Consumption

The final energy consumption matrix contains data showing the deliveries of commodities to all consumers that are not energy industries. The energy commodities are considered consumed and not transformed into others. In short, they disappear from the account.

The statistics contained within this part of the commodity balances are mainly taken from reports of deliveries made by energy industries to enterprises classified by principal economic activity or by direct survey of consumers. Classification of companies is undertaken locally, either by the energy company or by the national administration, using the national classification system for economic activities. Within the European Union this system will be directly comparable with the Statistical Classification of Economic Activites of the European Community *(NACE rev. 1)* and elsewhere countries have adopted or are adopting national classifications based on the *International Standard Industrial Classification (ISIC Rev. 3).* The two international systems are identical down to the three digit level. The widespread adoption of common classification schemes is essential for true comparability between the energy statistics of different countries. Despite the good comparability which currently exists users should always be aware that any time series of data may span periods when the national classifications used differed from the international norms then in place.

Quantities shown are intended to represent the energy needs of the economic activity under which they are classified. Within the Industry sector, for example, consumption of energy commodities will be for final use of the energy content without transformation into other commodities. In practice it is not always possible to ensure a clean separation of the statistics of fuels delivered for final use, as described here, and their use by the enterprise for transport, non-energy or electricity generation. Significant differences in taxation of similar oils for different uses, for example, may obscure identification of the correct category of use.

In general there are no statistics, provided on a regular basis, which describe the use of energy supplied; that is, whether for process heat, space heat, motive power etc. These useful data are usually obtained from occasional surveys of specific consumer groups conducted as part of special studies.

5.3.5.2.1. Industry

The industry sector is divided into ten branches. The NACE codes defining them are given in the annual questionnaires contained in Annex2. Only two branches need comment.

Quantities recorded as consumption by the chemical industry branch represent use of fuels for heat raising and not for feedstock use.

Similarly, figures for final energy consumption by Iron and Steel manufacture cover only the combustion requirements for heating coke ovens and blast furnaces. Quantities of coal and coke undergoing transformation, are reported within the transformation sector.

5.3.5.2.2. Transport

Four main transport modes are identified within this sector. The figures given relate to deliveries for the transport activity itself and not to consumption by the transport company for non-transport purposes. Usually the costs of transport fuels inhibits their use for non-transport purposes. Only three of the modes require comment.

Road: It is common for all road transport fuels to be shown as supporting the transport activity. Some will be used, however, off-road for digging, lifting and agricultural or forestry needs. Small but significant quantities will be used for pleasure craft and powered garden equipment. In general consumption for these diverse uses can be obtained only by survey.

Air Where separate data are available for deliveries of fuel to aircraft undertaking international flights the figures are shown in this sector rather than as international bunkers. (See the discussion under International Marine Bunkers above). In the absence of separate data all deliveries are recorded as to domestic air.

Inland Navigation: All fuel consumption for transport of goods or persons on inland waterways and for national sea voyages should be included. A national sea voyage is one which starts and ends in the same country without any intermediate foreign port of call. Note that an extensive part of the voyage may take place in international waters, for example, Bordeaux to Marseilles. Fuel consumed by fishing vessels of all types (inland, coastal or deep-sea) should be included under consumption for Agriculture, Forestry and Fishing.

5.3.5.2.3. Household, Commerce, Public Administration etc

This sector poses a number of difficult data collection problems particularly for the agriculture and residential sectors.

Agriculture: Energy use for forestry and fishing, including deep sea fishing is included. However, fuels delivered for deep sea fishing are sometimes omitted from this sector and included in international marine bunkers statistics. A small part of the deliveries of gas/diesel oil for road transport is consumed within this sector as "off-road" use of the fuel.

Residential: Statistics of energy consumption in households are collected in a variety of ways in different countries. Gas and electricity consumption data are usually derived from meter readings made by the utility companies. Consumption of stockable fuels may be obtained by difference between all deliveries and those to economically active sectors to whom deliveries are recorded. Some countries also conduct surveys of household energy consumption which serve to reveal any bias in delivery based statistics.

5.3.5.2.4. Military consumption.

Energy consumption by national or foreign armed forces is not explicitly identified within the commodity balances because only a minority of countries publish or make available the consumption data. Which element of the balance conceals the military consumption depends on the commodity and the country. Consumption of commodities for heating and lighting is usually included with household consumption whereas aviation fuels and marine bunkers are lumped with civil consumption or included with exports. In some cases the statistical difference may include the consumption.

5.4. ENERGY BALANCES

Introduction

The value of commodity balances is greatly enhanced if they are presented alongside one another in a manner which displays their relative magnitudes and the interdependencies arising from the transformation of one energy commodity into another. The energy content (enthalpy) of the commodities is chosen as a common and readily available measure and an energy unit as the unit of measurement.

This simplification is justified by the fact that most energy commodities are purchased for their energy content. Nevertheless, other characteristics of combustible fuels will be of importance to the consumer because they affect the conditions under which the fuel will be used and/or its environmental effects. In practice therefore the apparent interchangeability of commodities implicit in the use of a common unit is illusory as the possibilities for substitution of one energy commodity for another are considerably more limited.

The energy balance is usually derived from the commodity balances by calculating the heat content of the quantities shown in the latter. The specific heat content of a fuel may be expressed as the total heat release under ideal combustion conditions at constant pressure from unit mass of the fuel. The measured heat release will depend on whether water formed during combustion is retained within the measurement apparatus or whether it leaves the apparatus carrying away its latent heat of vaporisation. In the former case the *Gross Calorific Value (GCV)* is measured and in the latter the *Net Calorific Value (NCV)*. These are also known as the Higher and Lower Heating Values respectively. Certain solid fuels, notably coals and wood, are rarely free from moisture when combusted. It is usual for their NCVs to be measured using samples containing a level of residual moisture commonly found in them at the time of combustion. Energy balances are usually constructed using the NCV of the fuels as its measurement conditions are thought to represent more closely the conditions of their use.

As the quantities in the balance usually represent the energy contents of the commodities delivered or supplied this type of balance is termed the "heat supplied" balance.

Balances may also be constructed in which the heat supplied into final consumption is multiplied by the efficiencies of its different uses. The product, termed "useful energy", represents more correctly the consumers' actual needs and statistics prepared on this basis are of particular value for projections of energy demand, price effects and market shares. Despite the interest in useful energy balances they are not prepared widely. Even for the apparently simple cases of conventional fuel combustion the appropriate end-use efficiencies are not easily estimated as the concept goes beyond the technical efficiencies of combustion plant and embraces heat distribution and consumer practices. More complicated issues arise when defining end-use energy efficiencies for the non-power uses of electricity, lighting and computing equipment, for example.

Energy balances ignore the fundamental asymmetry between heat and electricity mentioned in *Section 1*. Although practically all the energy content of electricity may be liberated as heat or work only a minor part of the heat liberated from the combustion of fuels may be transformed into electricity. This fact has a considerable influence on the method used to represent primary electricity in energy balances and is discussed below.

In principle it is possible to construct energy balances using exergy rather than enthalpy as the property unifying the different commodities. Exergy, sometimes called "available work", is the capacity of a commodity to do work. This would have the advantage of putting heat and electricity on a comparable basis. However, calculating the exergy of a commodity at each point in the balance as it undergoes transformation is a complicated matter making demands for detailed additional information describing the conditions of heat supply. Such information is impracticable for regular data collection in a national data system. In addition, the concept is rather esoteric and difficult to comprehend. It is therefore poorly suited to the construction of a widely used statistical instrument.

5.4.1. Energy balance structure

Energy balances are prepared and may be published at many levels of detail. For working purposes it is desirable to assemble them with all the detail of the data collected through questionnaire system. This greatly simplifies checking the interdependencies of the energy processes and the consistency of the data. Such a balance would however be far too large and cumbersome to publish and use in a paper form. Consequently, most statisticians produce an energy balance which fits onto a single or a few A4 pages and it is this reduced format which will be referred to here although all the underlying methodological points contributing to the construction of the full balance will be explained.

Section 5.3.2. refers to the choice of transformation sector formats for the commodity balance. Similar choices may be made for the energy balance but if separate input and output sub-matrices have been adopted for the commodity balance then the identical format for the energy balance is the natural and elegant choice. The two sub-matrix balance is used by Eurostat and some national administrations. The single matrix alternative used by the IEA produces a more compact format but does not differ fundamentally as it is the arithmetic combination of the two sub-matrices (attaching negative signs to the input sub-matrix). Where energy balances present aggregated commodity groups use of the two sub-matrix structure has much to recommend it as the probability of both inputs and outputs appearing in the same cell becomes greater with the risk that the net output shown will give little indication of the magnitude of the activity.

5.4.1.1. Supply

Within the Eurostat energy balance the elements of supply are identical to those of the commodity balance. Their sum leads to the *Gross Inland Consumption* of the commodity group(s).

The coverage of indigenous production follows broadly the definitions given in the discussion of production under commodity balances. Other points bearing on what is or is not included as indigenous production are made during the description of the transformation sector. Two points concerning nuclear heat and hydro electricity production should be made here however.

Section 5.3.1. has mentioned the choice of nuclear heat as the primary energy commodity from nuclear power stations in the energy balance and the means whereby this information is collected.

The indigenous production of hydro electricity comprises all generation from natural water flow. It does not include electricity produced by water from reservoirs filled by pumping water from lower levels. At pumped storage plants electricity from lower cost, "base load", power stations is used to pump water into reservoirs for later release during times of peak electricity demand when the marginal cost of electricity generation is higher.

As the electricity required to pump water is generated by using fuels recorded in indigenous production or imports elsewhere in the balance any inclusion of pumped storage generation with natural flow hydro electricity would double count the energy content of the pumped storage generation in Gross Inland Consumption.

The energy lost in pumping, that is, the difference between the quantity of electricity used for pumping and that generated at pumped storage plants, is included in "Consumption of the Energy branch" under the "Electricity" column.

The criterion used for choosing the primary commodity for nuclear energy and non-thermal electricity generation has already been discussed in *Section 5.3.1*. Once a commodity has been selected and the production figures obtained there are two main approaches to calculating the primary energy equivalent of production for the balance.

The *partial substitution* method replaces the physical energy content of electricity by the energy content of combustible fuels needed to generate an identical amount of electricity in thermal power stations. Currently, an average consumption rate over all fuels is 238 tonnes oil equivalent per GWh which corresponds to a thermal generating efficiency of approximately 36 percent. The primary energy equivalent of nuclear and non-thermal electricity is therefore calculated at this rate, called the "conversion equivalent". Use of the partial substitution method makes total energy supply insensitive to changes in the shares of primary and conventional electricity in total electricity supply under conditions of constant electricity demand. This will be discussed after the alternative approach to calculating primary energy equivalent has been introduced.

The term "partial" appears to relate to the fact that substitution of the primary energy equivalent of a secondary commodity for the physical energy content of the commodity is only partly applied. Firstly it is applied to only part of the electricity balance as only non-thermal supply is substituted and the remaining elements are left untouched (but see later for a discussion of the partial substitution method in electricity trade). Second, the principle is not applied to changes in stocks of secondary commodities or their imports or exports shown in the supply matrix.

The *physical energy content* method uses the physical energy content of the primary energy commodity as its primary energy value. The primary energy commodities for nuclear energy and non-thermal electricity are the heat and electricity produced respectively. The energy content of electricity is 86 tonnes oil equivalent per GWh. Using the physical content of primary commodities makes the balance a record of the actual energy (enthalpy) flows from supply to consumption.

The primary energy equivalent of nuclear electricity calculated using the partial substitution method does not differ greatly from the energy content of the nuclear heat produced by the reactor and used in the physical content method. The differences observed result from differences between the thermal generating efficiencies of nuclear and conventional power plants.

However, applying the partial substitution method to non-thermal electricity production results in primary energy equivalents which differ considerably from the physical content method. One GWh of production from a hydro electric plant, for example, will have an energy content of 86 toe but a primary energy equivalent of 238 toe at present generating efficiencies.

The partial substitution method presupposes that the country has only a small part of its electricity supply from non-thermal sources. For countries where hydro electricity is a major source of electricity the method has little justification as it inflates the total energy supply and energy intensity indicatorsto levels which have no meaning in the context of a framework of energy consumption which has developed in the presence of plentiful hydro-power.

By adopting the partial substitution method for production any change in non-thermal electricity generation, under constant electricity demand, will be largely compensated by a rise or fall in conventional fuel use at power stations, provided that they are operating at efficiencies close to the average value assumed by the method. As the change in fuel use must be reflected in one or more elements of supply the total national energy supply, as expressed in the balance, will be practically unchanged by the relative movement of generating shares.

The method may also be used for external trade in electricity. Some countries for which electricity trade is important use the method to reduce the variation in Gross Inland Consumption when electricity trade changes sharply from year to year.

Almost all international organisations compiling energy balances have now abandoned the partial substitution method. Because of the difficulty of identifying a conversion equivalence factor which realistically represents the displacement effects of changes in non-thermal electricity production, the artificiality of applying such factors to "hydro" countries and the creation of artificial energy flows in the balance the physical energy content method is now used.

5.4.1.2. Transformation sector

The existence of transformation activities which link the supply of one energy commodity to the supply of others is the main *raison d'être* for the energy balance. There would be interest in expressing all energy commodities in a common unit if transformation did not exist, to obtain total energy consumption for example, but it is transformation which makes the energy balance essential as a succinct summary of the interdependencies.

Transformation sector statistics permit the user and statistician to identify the losses involved in the activities making up the sector. For the single transformation matrix structure the row sums represent the losses. The identification is less direct, but still simple, with the two sub-matrix structure where it is sufficient to subtract transformation input for "Total all products" into a given activity from the corresponding transformation output figure.

Electricity and Heat

Primary electricity and primary heat production are represented by their physical energy contents in the primary production row of the supply matrix. Figures for primary heat are carried down into the appropriate electricity generation rows (nuclear, geothermal or solar stations) of the transformation matrix and the corresponding electricity output appears in the electricity balance. When the partial substitution method is used for the calculation of primary electricity production the overstatement of actual energy input leads to a false view of the thermal losses due to electricity generation. Primary electricity is transferred from its identified source (wind, hydro etc.) to the electricity where it is distributed to final consumption. Final consumption of geothermal and solar heat is recorded in the appropriate sector. (See below). The table below shows the model for the presentation of primary electricity and heat.

Unit ktoe	Primary Heat	Primary Electricity	derived Heat	Electricity
Primary Production	1000	500		
Gross Inland Consumption	1000	500		
Transformation Input				
Public thermal power stations	150			
Autoprod. thermal power stations				
Nuclear power stations	300			
District Heating plants	450			
Transformation Output				
Public thermal power stations				50
Autoprod. thermal power stations				
Nuclear power stations				100
District Heating plants			400	
Exchanges, transfers and returns				
Interproduct transfers		-500		500
Consumption of the energy branch				25
Final energy consumption				625
Industry			250	350
Transport				40
Households, commerce, public administration	100		150	235
Statistical difference				

It is a simplified balance sheet in which the particular sources of primary and secondary heat and electricity are not identified so that the methodology for their presentation can be illustrated more clearly. For the same reason, electricity generation from combustible fossil fuel plants is ignored. In most countries not all of the activities implicit in the figures shown here take place or data are not readily available. For example in the table above, the 100 units of primary heat consumed by households and other sectors is assumed to come from direct capture/extraction by the user.

The Eurostat uses the term "derived heat" for secondary heat in its published balances.

The definitions of secondary electricity and heat production activities are different from one another and the nature of the difference has been described in.5.3.2.1. The reason for the difference derives from the need to have final energy consumption statistics which are accurate estimates of the energy needed to support the primary economic activities of the enterprises. This requires identification of fuels delivered for *final* use, receipts of heat and all electricity requirements.

Separation and identification of the electricity and heat flows is achieved by presenting all electricity production and its fuel use in the transformation sector but only heat production and fuel use relating to heat sold. Combustion of fuels by final consumers for the production of heat used on site is no different from other types of fuel consumption and is covered by the statistics of fuels delivered for final use.

Geothermal and Solar Energy.

Geothermal heat is extracted by two groups of undertakings. Major suppliers which extract the heat for electricity generation and/or sale by piped network and individual enterprises which extract heat for their own use. Statistics of heat extraction and use by this last group are difficult to obtain but for countries where the activity is widespread estimates are usually available. The presentation of geothermal heat in the energy balance is relatively simple and based upon the two forms of heat exploitation.

Geothermal heat consumption by individuals using their own supply is recorded in the final consumption sectors within the Geothermal heat column. Heat extracted and used for electricity generation and/or for sale by piped network is, as described above, presented in the electricity generation rows of the transformation input matrix. The corresponding outputs are shown in the "Electricity" and "derived heat" columns.

Solar energy is treated similarly although the part played in the total supply of solar heat by major suppliers is small compared with the analogous split for geothermal heat.

Heat Pumps

Heat Pumps were briefly introduced in the discussion of transformation activities under commodity balances where it was explained that, in the countries where they are actively used for exploiting ambient and waste heat, statistics of production and electricity use are usually available.

The principal difficulties arise when attempting to construct the energy balance as care is needed to distinguish "new", indigenous heat from "old", recovered (waste) heat in the heat produced figure and to identify the fuels consumed which provided the heat recovered. Failure to do this and treat recovered heat as indigenous supply risks double counting the energy content of recovered heat as the fuels used to produce it will have been recorded within the balance.

The methodology used has been prepared with the assistance of Swedish statisticians who have provided estimates for the division of production between "new" and "old" heat. The use of heat pumps is considered to be part of the "Heat Only" plant activity within the transformation sector. Electricity for the heat pump motor is recorded as an input to the plants. The estimated fraction (0.79, for Sweden) of the difference between the heat pump output and the energy content of the electricity consumed by the pump is reported as indigenous heat production from ambient heat sources in the heat column. The recovered heat component (0.21), together with the heat equivalent of the electricity used, is shown as output from heat plants in the heat column.

To complete the balance estimates are required of the amounts of fuels consumed corresponding to the heat recovered by the pumps. These estimates are then entered in the transformation sector on the heat plant row.

5.4.2. Consumption of the energy branch/final consumption

Methodologically the derivation and presentation of statistics of consumption of the energy branch and final consumption, for energy and non-energy purposes, are identical to that described for commodity balances. These sections should therefore be consulted for an understanding of the statistical issues involved in collecting and presenting the data.