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CONCEPTS AND METHODS IN ENERGY STATISTICS, WITH SPECIAL REFERENCE TO ENERGY ACCOUNTS AND BALANCES

A Technical Report

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PREFACE

At its nineteenth session, the Statistical Commission proposed the convening of "an expert group to consider the preparation of an international classification of energy and the adoption of a common unit of measurement for interfuel comparisons".* The Commission suggested that a consultant be engaged for the preparatory work in connexion with the proposed expert group. A report was prepared by Mr. W. N. T. Roberts, consultant to the United Nations, and submitted to the Expert Group Meeting on Classification and Measurement in the Field of Energy Statistics, held in New York from 6 to 14 March 1978. The Commission subsequently recommended at its twentieth session that "the report of the consultant, suitably amended in the light of the discussion of the expert group, should be made available for circulation to national and international statistical offices and other appropriate agencies.** This publication is issued in response to that request.

Additions to the report were made subsequent to the Expert Group Meeting by the consultant in order to incorporate information on new and renewable sources of energy.

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* Official Records of the Economic and Social Council, Sixty-second Session, Supplement No. 2 (E/5910), para. 12.

** Ibid., 1979, Supplement No. 3 (E/1979/23), para. 23 (b) (ii).

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SUMMARY AND RECOMMENDATIONS

This report reviews the nature of existing national and international practices in the area of energy statistics in the light of the significant shifts in emphasis from production to consumption as the main focus of interest since the events of 1973. The statistical problems raised by non-commercial sources of energy and the statistical requirements of the less developed countries are given particular attention. Its seven chapters consider successively the nature of energy statistics and the sorts of policy problem for which they are required, the conceptual and methodological issues to which these problems give rise, the variety of possible conventions that might be adopted for dealing with some of these issues, the key role played by quantitative overall energy balances, the desirable features of such balances whether used for analysing the past or for reasoned speculation about the future, the classification problems posed by energy statistics, and the relationship between such data and other economic statistics and accounting frameworks.

Chapter I deals with the similarities and differences between energy and other statistics and draws some parallels with agriculture. In both fields of study, a crisis in physical supplies promoted statistical innovation particularly in the development of physical accounting frameworks in which all the varied forms of nutritional or other energy could be expressed in terms of a common accounting unit. The change in emphasis from supplies as such to the uses made of available supplies, and the prospect of new sources of energy, posed new challenges to energy statisticians. Energy models, energy analysis and fuel use surveys are cited as examples of the new analytical approaches to problems in energy economics.

Chapter II outlines the nature of energy and the variety of physical forms in which it may be stored-up before it is made available for use as a source of heat, light or motive power. The chapter goes on to review the different levels of measurement, from the "primary energy" at the stage of production through "secondary energy" at the stage of transformation, to "energy supplied" at the stage of final use, and the essential features that need to be incorporated in an overall energy balance. The need to weigh up the costs and benefits of data collection, and the question of data quality are also discussed.

Chapter III explores the two types of boundary problem. The first concerns the energy system about which statistics are to be collected and analysed and, covers the boundaries between energy and non-energy commodities between commercial and non-commercial flows of energy, and between energy and non-energy industries. The second type of problem concerns the boundaries between certain flows and stocks and in particular between production and waste (with possible developments in solid fuel combustion technology and with gas flaring in mind), between production and stocks (with gas reinjection in mind), and between consumption, waste and stocks (with the partial fission of nuclear fuels in mind).

Chapter IV examines in greater detail some problems of accounting levels and accounting units, and in particular the application of the concepts of "primary energy equivalent" to the entities "final use", nuclear and hydroelectricity, renewable sources of energy (wind, geothermal and biomass energy), and foreign trade in both visible and invisible forms of energy. The chapter examines whether different energy sources should be expressed in a common accounting unit on the basis of gross or net calorific values, and then discusses the nature and limitations of converting different types of energy source (coal, oil, gas, electricity) into a single unit of account (e.g. the ton of oil equivalent or the joule), and reviews briefly the variety of accounting units and presentation units in current use.

Chapter V reviews thirty different energy balances currently produced by national Governments and research institutes, international organizations and research bodies, and major international oil companies. Most of these balances are used for analysing past years data but some are used as an accounting framework for making projections to future years or decades. Despite the great variety of structures displayed, all these accounts have common characteristics. Advantages and limitations of different structures are examined, and the relationship between frameworks suitable for backward looks and forward looks is analysed. A multi-purpose accounting framework is proposed for adoption internationally and, if possible, nationally as well. The recommended framework may be highly disaggregated in the case of the more developed countries and may be collapsed to a more aggregated form without altering its basic structure in the case of the less-developed countries.

Chapter VI examines the treatment of energy in the existing standard international classifications of commodities (ICGS, NIPRO), trade (SITC, NIMEXE) and industries (ISIC, NACE) as well as in the more aggregated classifications of economic categories (SNA and BEC). The need for grouping together all energy industries and commodities, and for a standardized nomenclature of petroleum products is underlined. Next, this chapter considers the possibilities of developing a classification of final uses of energy not merely by user but also by purpose, as a stage towards measuring a fourth level of energy flow, namely "useful heat". A framework in which heat recovery and temperature cascading could be accounted for is proposed.

Chapter VII considers the possibilities of producing energy balances for shorter periods than a year and for smaller areas than a country, and the desirability of publishing supplementary information such as percentage mixes, rates of change and flow charts. The relationship between the concepts and terminology of energy balances, input/output and national accounts is reviewed and the need for clarity emphasized. The chapter concludes with a plea for continuous consultation and active co-operation between all who are concerned as producers or users of energy statistics.

The report concludes with eight annexes on some more technical points.

Recommendations

In the above summary it was noted that recommendations are made as and when the argumentation of the text leads logically to a recommendation. In the following list, the order of recommendations has been changed so as to group together those relating to the same broad subject area.

Concepts and terminology

(1) Primary energy should be used to designate those sources that only involve extraction or capture, with or without separation from contiguous material,

cleaning or grading, before the energy embodied in that source can be converted into heat or mechanical work (para. 29; see also (16) below).

(2) Secondary energy should be used to designate all sources of energy that result from transformation of primary sources. Fuels, alone, should be used only when describing those energy sources, whether primary or secondary, that must be subjected to combustion or fission in order to release for use the energy stored up inside them (para. 29).

(3) Imports, exports and stock changes in secondary energy should be treated in an energy balance in the same way as to changes in the supply and use of primary energy. These flows of secondary energy should be designated as primary energy equivalent. Bunkers should be treated in the same way, as part of the "primary equivalent flows" (para. 30).

(29) In order to avoid possible confusion between the meanings of "final" (and "intermediate") in national accounts, input/output and other economic analyses on the one hand and in energy balances on the other, table and texts that refer to the flows involving the energy transformation industries and/or final users of energy should always make clear what is meant by "final" (and - if the term is used - "intermediate") (para. 315).

Energy balance coverage

(7) (a) An overall energy balance should cover all flows of energy including the so-called "non-commercial" sources. Coverage of such sources should be as extensive as possible. When such sources are known to be important but little data exist, such steps as sample surveys should be instituted to improve the amount and quality of data;

(b) Autogeneration of electricity from purchased fuels, with or without the joint production of heat, should be treated as part of the transformation sector;

(c) Autogeneration from industry's own hydropower should be treated as primary production of electricity;

(d) Steam or hot water produced by the combustion of industrial (or urban) wastes or by exothermic or other heat recovered within industry, should be recorded as primary production;

(e) Each method of electricity generation contributing a significant amount of the total supply of electricity should be assigned a separate row in an energy balance (para. 62).

(6) Energy balances should cover only all the supplies and uses of primary and secondary energy sources, showing clearly the non-energy use of such sources (para. 54; see also (8) below).

(8) (a) Energy balances should only cover all the hydrocarbon commodities as defined by a list either embodied in or accompanying the balance table (chap. V).

(b) The problems of defining and obtaining more complete data on the gross and net energy flows between oil refineries on the one hand and petrochemical plants on the other should be investigated more fully. Satellite tables to an overall energy balance should usefully show as fully as possible at least the more important flows of energy by-products (and recovered heat) within the major branches of the chemical industry (para. 65; see also (6) above).

(13) An energy balance should show all flows at each level that can be adequately recorded with existing data, so that the relationships between primary energy inputs to transformation, secondary energy outputs from transformation and transformation, losses can be clearly seen. For some purposes, as a supplementary statistic, primary fuel input equivalent of secondary energy sources delivered to final energy users is useful, but may be difficult to estimate because of lack of sufficient data (para. 92).

(27) National and international statistical offices should consider publishing estimates of the quantities of useful energy consumed by each final consumption sector. Such estimates should be accompanied by details of the methodology used (para. 292).

<u>Primary energy inputs for the generation of electricity in nuclear and hydropower plants and to renewable forms of energy</u>

(14) The primary energy input to nuclear electricity should in principle be defined as the heat released by reactors during the accounting period. In practice, a proxy for this may need to be used, namely the figure obtained by dividing generation of nuclear electricity by the average efficiency of all nuclear power stations (para. 99).

(15) The primary energy input to hydroelectricity should be defined as the energy value of the electricity itself. The energy equivalent in fossil fuel should be recorded as an additional statistic, using, for simplicity either the average thermal efficiency of all classical thermal stations in the country concerned or a standard efficiency of (say) 35% (para. 105).

(16) The primary energy corresponding to the so-called renewable sources of energy should be defined as follows and applied to the output of the first stage in an energy-capturing process that yields a measurable output of heat, electrical or mechanical energy:

Solar:	Biomass	Heat output of the fermentation, distillation or combustion device
	Photovoltaic cell	Electrical energy output
	Other collecting device	Heat output of the device
Water and air:		Mechanical, heat or electrical output of the device
Geothermal and ocean thermal:		Heat of output of capturing installation.

Economists and engineers working on the conversion efficiencies of these techniques may need, in addition, to assess the "potentially recoverable energy" that is awaiting "capture" (para. 114).

Imports and exports

(17) Imports and exports of secondary sources of energy should be recorded for an overall energy balance in terms of the energy content of the fuels (or electricity) that actually flows across national frontiers. If a more detailed analysis is needed of the primary energy input to foreign trade, such an analysis can be made, but it should be additional to, and not part of, the overall energy balance. Trade in non-energy products derived from primary energy sources (e.g. lubricants, carbon black, electrodes) should be recorded in the main energy balance (para. 127).

(18) International trade in embodied energy is a proper subject for a detailed assessment of energy problems. Nevertheless an overall energy balance should be constructed in the first place on the basis of, among other flows, only visible trade in energy sources (para. 130).

Accounting units and conversion factors

(25) Energy balances should contain in the column headings for each energy source the average conversion factor (appropriate for expressing the original units in (or underlying) that column in terms of the common accounting unit as shown in the balance). Such average factors should be complemented in foot-notes, or accompanying text, with clear descriptions of the routes and stages followed in any conversions that are not adequately defined by the average factors (para. 268).

(5) National and international statistical offices, and bodies that advise them or undertake work for them, should always define clearly the accounting units or presentation units employed in published analyses. The conversion factors and the route used to convert original physical units into the chosen common accounting unit or units should also be stated, or readily available published sources where they may be found should be cited. It should also be made clear whether energy units are defined on a gross or net calorific basis (para. 48; see also (19) and (20), below).

(19) When expressing the energy content of primary and secondary fossil energy sources in terms of a common energy accounting unit, net calorific values (NCV) should be used in preference to gross calorific values (GCV). If and when recuperation of a significant part of the difference between GCV and NCV from exhaust gases becomes a practical possibility and seems likely to become a reality, this recommended basis may need to be reconsidered (para. 135).

(20) Given that the joule, and multiples of it by raising it to powers of 10^3, is the only energy unit in the SI, international and national statistical offices should consider adopting the joule (1 joule = 0.239 calorie) as the rigorous accounting unit for energy balances. The TOE (1 TOE = 10^7 kcal NCV) and/or TCE (1 TCE = 7×10^6 kcal NCV) may be used as supplementary presentation units. Whenever they are used, they should be clearly defined in terms of the joule, and the route used for converting original data to TOE or TCE should be clearly described (para. 157).

Accuracy of data

(4) National and international statistical offices should consider seriously attempting to assess the sensitivity of each major published aggregate in their energy statistics to errors of plus and minus (say) 5 or 10% in the less reliable components of such aggregates (para. 43).

(24) The relationship between the original-unit data, as used for an energy balance and as published in the usual statistics about each energy industry, should always be made clear (para. 267).

Energy balance structure and classifications

(21) Over-all energy balances should be constructed in the matrix form with the following characteristics:

Columns show energy sources (energy commodities)

Rows show flows from origins to uses of energy (energy transactions)

Separate sub-matrices show, respectively:

(a) Supplies of primary sources and equivalents;

(b) Transformation inputs (with negative signs) and outputs (with positive signs); transformation losses in the total column (with negative signs); energy industries' own use; transmission and other losses;

(c) Final uses (para. 253).

(26) Existing classifications and definitions of crude hydrocarbons and derived products should be examined with a view to establishing an agreed international set of designations, groupings and definitions (para. 286).

(28) National statistical offices should consider constructing end-use analyses of the type illustrated in the table following paragraph 306.

Coverage of particular flows

(9) Published energy balances, whether for particular energy sources or for all energy sources in a single table, should always make clear whether flows represent production, deliveries, receipts or consumption, and the coverage of stock changes (and stock levels) should make clear whether or not they cover producers, importers, transformers, distributors and final users' stocks (para. 69).

(10) Production of coal should be defined as extraction from the ground <u>less</u> waste and screenings <u>plus</u> recoveries from the waste pit (para. 76).

(11) All production of associated gas should be treated as part of production of gas, and that part that is flared should be so described. In this way, the change in the output of the production of oil and gas will not show a "step-change" when the use of part of the gas changes. By analogy, total

production of oven gas and blast furnace gas should be recorded in an energy balance, with amounts bled to waste shown as losses (para. 78).

(12) All production of gas, either associated or non-associated with crude petroleum, should be recorded net of injection of gas into gas or oil fields. If injected gas is later extracted for a second time, it should be treated as produced then for the first time (para. 80).

(22) Electricity output from pumped storage should not be added to electricity produced by other methods (because the latter already includes the electricity that is redistributed through time by means of pumped storage) when compiling an energy balance. The difference between the input to and the output from pumping should be treated as part of the electricity industry's own use (para. 264).

(23) Materials returned to oil refineries should be included as inputs to refining, even though such materials have previously been accounted for in refinery output. Refinery fuel should also be included both as part of output and as part of own use (para. 265).

EXPLANATORY NOTES

Reference to tons (t) is to metric tons unless otherwise stated.

Besides the abbreviations of classification systems given in annex IV, the following acronyms have been used:

CBI	Confederation of British Industry
CEREN	Centre d'Etudes Régionales sur l'Economie de l'Energie (France)
CMEA	Council for Mutual Economic Assistance
ECE	Economic Commission for Europe
EEC	European Economic Community
ENI	Ente Nazionale Idrocarburi
ERG	Energy Research Group
FEA	Federal Energy Agency
IEA	International Energy Agency
IEE	Institute of Energy Economics, Japan
IEJE	Institut Economique et Juridique de l'Energie, France
IFIAS	International Federation of Institutes for Advanced Study
MIC	Ministry of Industry and Commerce, Italy
NEDO	National Economic Development Office
OECD	Organisation for Economic Co-operation and Development
OIW	Oesterreichisches Institut fuer Wirtschaft
OSZ	Oesterreichisches Statistisches Zentralamt
SI	Système International d'Unités
SOEC	Statistical Office of the European Community
UNIPEDE	International Union of Producers and Distributors of Electrical Energy
WEC	World Energy Conference

The following technical and special abbreviations have been used:

BTU	British thermal unit
CHP	combined heat and power
EJ	exajoule
FBR	fast breeder reactor
GCV	gross calorific value
GJ	gigajoule
GWh	gigawatt hour
HWR	heavy water reactor

J	joule
kcal	kilocalorie
kg	kilogram
kWh	kilowatt hour
LWR	light water reactor
m^3	cubic metre
m^3 + kcal	cubic metre or kilocalorie
MJ	megajoule
NCV	net calorific value
n.e.s. (in tables)	not elsewhere specified
Pu	plutonium
t	ton
Tcal	teracalorie
TCE	tons of coal equivalent
TJ	terajoule
Th	Thorium
TOE	tons of oil equivalent
U	uranium

I. ENERGY AND OTHER STATISTICS

A. Some important differences

1. Energy statistics might at first sight seem to be just one branch much like any other in the wide field of economic data, with other branches covering statistics on topics such as agriculture, iron and steel, transport, distribution and manpower. In fact, energy statistics have their own particular characteristics which are shared only in part by some other branches of economic data. While many other industries dispose of their output to nearly all other industries in the economy, only a few, such as chemicals, metal goods, paper and printing, and the energy industries taken together, supply their main output to every single other industry as well as to all categories of final consumer in the national accounts sense (see chap. II). The characteristics of the output of the energy industry are more heterogeneous than the components of the output of any other industry except chemicals: they include solids, liquids, gases and electricity and their only common feature is that all can produce heat. They differ greatly from each other in the convenience with which they can be used for producing not only heat but also light or motive power. They also differ greatly in the ease with which they can be stocked, transported, controlled and used. They can be transformed between each other in certain directions, but only at considerable cost. They can be substituted for each other in the short run to different degrees, depending on the uses to which they are to be put and on the stock of equipment capable of harnessing them. The amount of energy present in a given energy source that is effectively converted into useful heat or work depends on the efficiency of the device, machine or process that makes the conversion, and this conversion efficiency varies widely between uses and can vary in the same use between different users. In some ways, energy production and use is more similar to agriculture than to other economic activities. In both fields, in many developing countries, production and own use outside the market are more important than flows through the market itself. The energy commodities (e.g. fuel-wood, water power) may be untypical of predominantly market economies but the energy obtained, usually as heat or mechanical power, could in different circumstances have been obtained from, for example, coal or oil. The energy producing industries also produce some non-energy products that need to be taken in account when studying those industries.

2. In manufacturing industry taken as a whole, production of any given commodity is generally concentrated in a very small number of industries - indeed industries are commonly defined in terms of the characteristics of their principal product. In the energy sector, one particular type of product (electricity) is produced as a "secondary product" on a significant scale in a very wide range of industries outside that whose "principal product" it is (namely the public supply electricity industry). Much of this "own produced" electricity is used within the industries where it is produced, but some is also sold to the public electricity supply industry. Further, much of this autogeneration by industry is through combined heat and power systems (which provide electricity and recovered steam simultaneously). Most of the steam is used within the industry that produces it, but small quantities may be sold either to nearby establishments in other industries or for district heating. Sometimes the heat input to an industrial process is itself obtained from the exhaust heat from a higher temperature process in the same establishment, and in this way the total quantity of purchased energy is reduced. In some industries, both in developed and in developing countries, steam or heat is generated by burning the waste products of the manufacturing

process (e.g. wood-waste, bagasse). These energy-producing activities outside the energy industries (as narrowly understood) pose problems when the boundary of the energy system to be covered by energy statistics is being defined. The problem is further complicated by the fact that heat generated by exothermic reactions in the chemical industry may be recovered and used for steam-raising or other purposes. Such heat is a secondary energy output from non-energy chemical feedstock inputs.

3. Energy statistics illustrate more clearly than many other branches of economic data a wide range of conceptual problems, only some of which occur in most other branches. Energy statistics have much in common with national accounts. Frequently, as subsequent discussion in this manual will show, there is not an obvious and only right answer on how to measure a quantity or how to add together two or more stocks or flows. There is often a need to adopt an acceptable convention on how to resolve a problem. Sometimes the balance of advantage between two or more alternative solutions is far from clear. On occasions it may even be desirable to adopt two conventions at the same time, even though this procedure results in two different totals or sub-totals incorporating the two different bases for treating one or more figures in the analysis.

4. Another feature of wider relevance that emerges in discussing the basis for energy statistics is the importance of trying to understand the conceptual principles that should be applied in particular cases in order to ensure consistency in all cases while at the same time recognizing - as in other analytical fields - that the quantitative importance of not applying rigorously the required principle may be negligible. It is nevertheless important in such cases to recognize and acknowledge that one is deciding positively not to apply a principle.

B. <u>The shift in emphasis since 1973</u>

5. The changing pattern during the past 25 years in supplies of different sources of energy - coal, oil and natural gas in particular - and the induced changes in the pattern of use of these various energy sources coupled with the interaction between demand and supply, have led to great changes in the size and shape of national energy industries and of international trade in different types of fuel. Not surprisingly, the extent, coverage and sophistication of energy statistics have varied greatly between countries. Energy statistics usually begin as independent sets of data needed for the running of particular energy-producing industries. Electricity and, until recently, gas-works gas statistics necessarily gave rise to some cutting across fuel boundaries, since each depended upon two or more inputs in order to produce the output of that particular source of energy. At the same time, however, because of the long lead-times needed to build a new power station or a new refinery on the one hand, and the production of more electricity or more petroleum products on the other, and because of the relatively long economic life of such installations once they had been constructed, decisions to embark on such investment necessarily required attempts to forecast the future demand for energy as a whole and the market share of the output of the industry in which the investment was being considered. Apart, however, from these investment decisions, before the energy crisis of 1973 there was relatively little interest, nationally or internationally, 1/ in any other detailed statistics which related all the different forms of energy to one another, tracing through supplies from their origin in indigenous production or imports, through transformation into derived forms of energy and so to final use of primary or derived energy forms.

6. The events of 1973 with the cut in oil supplies and the tenfold increase in the price of crude oil suddenly produced a completely new interest in oil in the context of energy as a whole. Questions that pressed for an answer were: How important was oil? What were the direct and indirect effects on various industrial product prices of the oil price rise? 2/ How far could fuels of all kinds be better used or used less, so that, among other fuels, less imported oil would be needed? What was the future outlook for oil reserves in the traditional areas in which it was produced, and what were the economics of exploration and production in areas not hitherto regarded as a likely source of crude oil? What would be the likely impact on capital markets and company structure of undertaking the huge amounts of investment needed? What Research and Development would be most worth undertaking in pursuit of alternative non-oil sources of energy? What were the economic and technological obstacles to capturing some of the energy in the wind, the waves, the tides and the sun's rays? At what rate should the newly discovered oil reserves of the north-west European Continental Shelf be depleted? At what rate should existing coal mines be exploited and new pits dug? What contributions to total energy supplies could or should be made by nuclear electricity?

7. With growing concern about the number of years or decades for which existing non-renewable sources of energy could be relied upon, and with increased attention being given to the need to find alternative sources of energy and to explore ways of making better use of the energy sources now available, there has been a dramatic shift of interest by energy analysts and by those concerned with energy policy away from the problems of particular energy industries to the problem of trying to assess the future outlook for energy supplies and uses of all types taken together. This shift from interest in fuels separately to fuels in total has been accompanied by a marked shift from interest primarily in the supply side to concern with the uses to which fuels are put.

C. Energy analysis: a new field of study

8. A few countries (e.g. Netherlands, Norway and Poland) have for some time been actively interested in the energy content of manufactured products as one statistical input to industrial management decisions. The post-1973 situation in the world energy scene gave rise to a new interest in what has come to be called "energy analysis". So great has been the activity in this field by economists, engineers, physicists and statisticians that a special workshop 3/ was organized in 1974 by the International Federation of Institutes for Advanced Study (IFIAS) to seek agreement on concepts and terminology. A second workshop 4/ was convened a year later to explore more fully the interface between energy analysis and economics and in particular the questions of measurement of efficiency and the integration of energetic information with economic information on behavioural relationships.

9. Energy analysis seeks to trace and quantify not only the readily recognisable and measurable direct energy input to a process or a product but also the upstream indirect energy inputs. These can be defined with an ever widening coverage, starting with the energy used in extracting, transporting and processing the sources of energy used in the given process. This coverage can be widened to embrace the corresponding energy inputs needed to deliver the raw material or other non-energy inputs to the process. The coverage may be widened still further to include the energy inputs to the capital equipment used in the process and in the upstream capital-supplying industries, and the energy content of imported and

exported goods. This type of analysis may start either from mapping the upstream inputs to a given product or process, 5/ or from a conversion into quantitative terms of the money-value estimates of the direct and indirect energy inputs to a wide range of commodities or industries using the basic data from input/output tables as a starting point. 6/ There has been much discussion of the practical value of this type of analysis, 7/ but interest in it is unlikely to disappear.

D. Fuel use surveys

10. A second area of intensified analytical and statistical activity is the investigation at the level of the plant or establishment and including commercial, government and residential buildings, the use of energy according to purpose (e.g. heat, light, motive power). The energy industries in some countries were of course interested in making forecasts of the scope for expanding sales of appliances that would ensure use of their particular energy carrier. Regular surveys of appliance ownership are conducted in some countries but systematic surveys of fuel use by purpose have been unusual. Fuel use surveys or energy audits of this kind have rarely been attempted before because of the high cost of data-gathering in relation to the limited size (in money terms) of fuel saving that might have resulted and the limited interest in such cost saving before 1975. Now, however, they are of considerable importance in a number of countries. 8/

E. New sources of energy

11. Perhaps the most dramatic event of all resulting from the oil crisis of 1973 is the attention now being given to the new or renewable sources of energy. Historically, these sources - the sun's rays, the winds, tides and waves, and the hot rocks beneath the earth's surface - are older than the fossil fuels (but perhaps contemporary with the atoms that man himself now breaks down through nuclear fission and aspires to create through nuclear fusion). A lot of effort has been put into seeking ways of reducing further destruction of forest for fuel-wood. Cow-dung might be better used as fertilizer rather than as a dried fuel for cooking and heating. Alternative energy sources might be more efficient than wood and charcoal burning stoves. Crop drying and food processing may increasingly be carried out using heat and mechanical power from solar, water or wind-powered devices with or without electricity as an intermediate stage. Brazil has a programme for the cultivation of sugar cane and cassava as sources of alcohol for use in transport fuel. Fiji has been investigating the feasibility of using treated coconut oil as a diesel substitute. Mexico has plans for using pumps powered by solar energy to irrigate areas at present useless for agriculture. Statistically speaking, these new sources pose a number of conceptual and practical problems which we shall consider later in this paper.

F. Energy models

12. During the past 10 years or so, a growing number of national and international governmental and other agencies have been elaborating and running mathematical models of the energy supply and use system as a basis for assessing the likely effects of different energy scenarios on supplies, demand and prices for each main source of energy, and the scope for and likely impact of different forms of electricity generation on other forms of energy supplies and uses. It is

increasingly important for Governments and others concerned with these problems to be able to compare the results of different investigations and assessments particularly at the international level. Assumptions may legitimately differ between different investigators but the basic data and conventions should in principle be common to all such exercises. This agreement on basic data covers not only internal consistency within any one supply and use account for any one particular source of energy, but also for consistency between different fuel accounts within any one country (so that, for example, disposals of coal and petroleum products to electricity generation are consistent with the inputs of these two types of fuel used by the electricity generation industry during the accounting period concerned). Secondly, there is need for consistency through time in the data for any one country, and further there is a need for consistency between countries both at any one point in time and through time. This need for both internal and external consistency applies, of course, to energy statistics covering more than one energy source for all analytical purposes not only in the case of models of the general types referred to above.

G. The summation problem

13. Despite the very different characteristics of solid, liquid, gaseous and electrical sources of energy, all are nevertheless substitutable to some degree over a wide range of uses. It is therefore logically permissible, and economically necessary, to have an overall accounting framework in which all sources of energy - or at least all those relevant to the analysis - can be expressed in a single accounting unit so that the flow of each can be traced from its origin in production or imports through transformation to delivery (with or without transformation) to exports or to inland final energy users.

14. The summation problem arises in such a challenging way outside the area of energy statistics, perhaps only in the field of agriculture and food. In both fields - energy and agriculture - the traditional solution of resorting to prices and values is not satisfactory for all purposes, since prices are influenced by market forces, social and fiscal policies that do not necessarily reflect the inherent energetic values and other characteristics of the commodities concerned. Prices for the same energy source may be different for different users or uses. Prices change through time, although the energetic characteristics of the fuels stay constant or change very slowly. It is interesting to note that since both energy and agriculture (and food) are concerned with energy, not surprisingly both areas of statistics have used an energy unit - the kilocalorie - as one of the main non-money accounting units for some purposes.

15. It is also interesting to note that it was a crisis about energy supplies (occasioned by interference not with production but with the international distribution of agricultural products during World War II) that gave a big push to the development of aggregated statistics of agricultural commodities. Crisis gave rise to statistical innovation: it was suddenly of great importance to see all food statistics as interrelated sets of stocks and flows in which each type of food could be assessed both absolutely and in relation to a total for all food. (Over-all food balances were developed in North America and the United Kingdom as a basis for food sharing and import programming in those trying times, and household surveys were introduced as a means of monitoring the end-use of primary and derived food products.)

H. Energy balances

16. An overall energy balance shows in a coherent accounting framework the stocks and flows of all forms of energy from their origins through to final uses. Such a balance provides a basis for rigorous analysis and synthesis which can ensure just those types of consistency mentioned above. While not replacing detailed statistics on separate forms of primary and secondary sources of energy (see later in this report), compilation of an overall energy balance constitutes a key test of internal and external consistency within and between separate energy commodity balances. Such an overall energy balance is at the same time a key framework around which to build more elaborate analyses, where these are more detailed, than can conveniently be incorporated in the basic balance itself.

17. In the case of countries with relatively simple economies and with relatively uncomplicated statistical systems, a condensed form of the overall energy balance is an invaluable guide to the types and range of basic data, at least some of which should be sought in building up a system of national energy statistics. At the same time, the more sophisticated countries and economic institutes can and do use simplified energy balances for the presentation of the results of their more detailed analyses.

18. Some countries have published energy balances of one sort or another for many years. Other countries have only recently introduced such an overall supply and use account. A number of these balances are reviewed later in this report. For more than 20 years the Statistical Office of the European Communities (SOEC), Luxembourg, has been constructing for each of the original six members of the European Economic Community (EEC), fairly detailed overall energy balances. Since the addition of the United Kingdom, Denmark and Ireland, SOEC has done the same for these latter countries. The United Nations Statistical Office has published for many years a very simple overall balance of primary fuels. In 1974, the Organisation for Economic Co-operation and Development (OECD), produced for the first time an overall energy balance for each of its member countries which was simpler than that produced by the SOEC.

19. Almost any one of these national or international energy balance frameworks could have been used as a basis for analysis on a country, regional or world level of past trends and future ranges of possibility for energy supply and use, but the results would have been different in each case because of the number of significant differences in the accounting units, conversion factors, classification and conventions adopted for recording the multifarious flows of energy of different types to different uses.

I. Aims and scope of the present manual

20. There was manifestly a need to review all these different national and international practices, and this was done as part of the preparation of the present Manual. Its immediate aim is to promote discussion of the main problems, to offer guide-lines on number of conventions and concepts, and to identify certain areas that cannot be fully mapped out for harmonized conventions until more is known about likely future developments in energy technology.

21. It is recognized that many compilers and users of energy balances may be reluctant to make some changes in their current practices, since statistical

innovation can, though it need not, mean discontinuity. Such reluctance should not deter users and producers of energy statistics from adopting as wide an area as possible of commonly agreed accounting conventions, practices, frameworks, classifications and units for use in international comparisons and for publication by international organizations.

22. The adoption of an agreed international standardized system would not prevent countries from departing from the conventions of such a system for good and sufficient reason in their own national statistics, but it would ensure that there was a commonly accepted international basis for making comparisons of national statistics for a wide range of purposes. In matters of energy more probably than in any other context, no country is any longer an island - if ever it was - and international comparisons are an unavoidable part of both national and international studies of perhaps the single most important input, apart from human effort, into all economic activity.

23. This Manual not only considers what is desirable in statistical terms for sources of energy that are currently important but it also examines how new and renewable sources of energy could be fitted into the proposed accounting framework. As noted above, it considers how a standardized accounting framework could be simplified without detracting from its essential structure so as to be suitable for use by countries whose energy economies and statistical systems are as yet relatively unsophisticated.

24. This Manual is concerned essentially with conceptual, classification, accounting and measurement problems in the field of energy production, conversion and use in physical or energy units of some kind. It does not consider the statistical problems posed by the definition and measurement of energy reserves, resources or prices and money values except in so far as such problems emerge through the interface between the concerns of this Manual and these other related spheres of study.

25. A benefit of more than negligible importance of the adoption of a standard framework for energy commodity balances and for overall energy balances would be agreement among all major international organizations on a harmonized set of questionnaires on energy, so that countries would only have to fill in such a set of tables once. Thus members of the EEC would report once and once only to SOEC, Luxembourg, and the same data would be sent to OECD (Paris) and to Economic Commission for Europe (ECE), Geneva, which would also receive from the Council for Mutual Economic Assistance (CMEA), Moscow, corresponding figures for member countries of that organization; ECE would pass on to United Nations Statistical Office, New York, the figures in respect of all its member countries, which in turn would receive similar figures from its other regional offices in respect of member countries in those regions. This would not only avoid the present position of scarce statistical manpower and other resources being tied up in the completion by most countries of two or more different questionnaires using different units and conventions, but it would also ensure consistency between data published by different international organizations according to the internationally agreed system of energy accounts. This would without doubt be to the benefit of all who are concerned with energy analysis and policy problems at national and international levels.

II. BASIC IDEAS

A. Meanings of "energy"

26. The words "energy" and "energy statistics" have been used without definition. Before going on it may help to try and be more precise about their meanings. "Energy" means the capacity for doing work or for producing heat; energy can be regarded as "stored work". The heat produced may be so intense as to emit light. Heat, light, motive force and chemical change induced by, or resulting in, electricity cover sufficiently for the present purpose the range of manifestation of "energy". The combustible sources of energy may be transformed into mechanical energy (or motive power) 9/ with or without subsequent transformation into electricity. Mechanical energy and electricity may also be derived from the kinetic energy of a mass of water that moves from one level to another (whether from a dam, in a river, between tides or between waves) or from a mass of air that moves from a higher to a lower pressure area. Heat may be produced through combustion or fission of a suitable fuel, compression of a suitable liquid or gaseous medium, from passage of electricity through an appropriate material, from capture of the sun's rays, from hot rocks below the surface of the earth, or from certain exothermic chemical processes other than combustion. (An exothermic process is one that gives out heat. An endothermic process is one that absorbs heat.)

27. Each source of energy has its particular advantages and disadvantages. Fossil and fissile fuels and water can be fairly readily stored. Geothermal energy is of its nature stored in, until released from, its subterranean origin. Solar, wind and wave energy cannot be stored as such, but - leaving aside photosynthesis from sunlight - each energy source may be transformed into a storeable form such as water pumped to a level from which it may later flow through a turbine to extract at least a proportion of the original energy. Liquid and gaseous sources of energy can be particularly conveniently transported (by pipelines or in movable tanks) and of course solid fuels can be readily transported in trucks or lorries (and, if somehow made suitably fluid, by pipeline too). Electricity is the most convenient of all to transport, control and apply to a wide variety of uses, but it cannot (at least at present) readily be stored as such in large quantities economically.

28. It has been customary to speak of those sources of energy that occur naturally such as coal, crude oil and natural gas, as "primary fuels", and those that are derived from these primary fuels, such as coke, petroleum products and gas-works gas, as "secondary fuels". (One should now add fissionable materials to the list of primary fuels.) A more formal definition would state that primary fuels are not derived from any other source of energy. Either primary or secondary fuels may be converted into electricity, and one might argue that electricity should therefore be called a "tertiary fuel". Such terminology seems to be needlessly complicated and there is the slight difficulty that electricity as such is not a fuel but a form of energy, and that it may be produced otherwise than from fossil fuels (e.g. from hydroenergy or sunlight).

29. An alternative would be to distinguish between "energy carriers" or "energy sources" on the one hand and "energy" on the other. Using this terminology, electricity is a form of energy and all other forms of energy, heat, light, motive force, are derived from either the combustion, fission or capture of energy sources. The designation "energy source" could very aptly be applied not only to

fossil and fissile material but also to hot rocks and to the renewable sources (solar radiation, wind, moving or suitably located standing water, and biomass). However, statistics on the supplies and uses of energy generally relate to the quantities of energy derivable from each source, and it is therefore convenient to define energy derived from primary sources as primary energy and to define all other energy as secondary energy. Note however that "secondary" does not mean "lower grade" - on the contrary, secondary energy is in most cases of much greater usefulness than the primary energy from which it originated.

RECOMMENDATIONS:

(1) Primary energy should be used to designate energy from sources that involve only extraction or capture, with or without separation from contiguous material, cleaning or grading, before the energy embodied in that source can be converted into heat or mechanical work.

(2) Secondary energy should be used to designate energy from all sources of energy that result from transformation of primary sources. "Fuels", alone should be used only when describing those energy sources, whether primary or secondary, that must be subjected to combustion or fission in order to release for use the energy stored up inside them.

30. For completeness, two other concepts are mentioned at this stage, although some aspects of them are dealt with more fully later. By extension of the idea that primary energy is not derived from any other form of energy (and we ignore by definition the direct and indirect energy inputs to the processes of extraction, preparation and transport of the primary energy sources), imports and stock reductions for secondary sources are, so far as any particular country is concerned, equivalent to increments in the primary energy available to it. Exports (and bunkers) and stock increases are negative increments. Thus more generally, net trade and stock changes in secondary energy are equivalent to changes in supplies of energy that is "primary" as seen by the country concerned and can be conveniently designated as "primary energy equivalents".

RECOMMENDATION:

(3) Imports, exports and stock changes in secondary energy should be treated in an energy balance in the same ways as changes in the supply and use of primary energy. These flows of secondary energy should be designated as primary energy equivalents. Bunkers should be treated in the same way, as part of the "primary equivalent" flows.

31. The second concept arises from the following considerations. When primary sources (e.g. coal, oil, natural gas) are upgraded into more convenient or, for many purposes, more useful secondary sources (e.g. coke, motor spirit, electricity) in the energy transformation industries (coke ovens, oil refineries, power stations), significant amounts of the primary energy are used up or lost in the process. In the case of electricity generation other than hydro, these losses amount to about two thirds of the primary sources fed into the process and are emitted as waste heat into the atmosphere. These emissions are of importance to environmental statisticians for whom they are one form of atmospheric pollution, and to energy economists for whom they are one source of potentially recoverable low-temperature heat.

32. Irrespective of what happens to this exhaust heat, the energy it contains is the energy cost 10/ of obtaining the desired quantity of secondary energy. Even though only the coke or petroleum products or electricity is delivered to and used by a final user of energy, that user's demand can only be met by making available for him as inputs to the transformation industry the primary and secondary energy that are required as an input by that industry. This quantity represents the total energy value of one or more derived sources of energy on a primary energy input (or fossil fuel equivalent) basis. It indicates the amount of energy that would be needed (in fact or on a stated assumption) as the direct energy input to the transformation process in order to produce a given amount of secondary energy. We return later to the question of the assumptions.

33. The direct energy cost, defined in this way, is relatively small for the production of solid fuel products, petroleum products and manufactured gases and is ignored in some "bottom up" energy balances 11/ but the fossil fuel equivalent of nuclear, hydro and geothermal electricity is of great importance conceptually. 12/

B. Meaning of "statistics"

34. "Energy statistics" implies with undue simplicity that the figures designated by this description are all fairly objective and readily determinable facts. This is not the case. The production of coal or the generation of electricity expressed in their own natural units (e.g. metric tons for coal and kilowatt-hours for electricity) may be fairly readily measurable facts. The whole object of an overall energy balance, however, is to present in a single supply and use account the stocks and flows of all these dissimilar forms of energy. This means that some common accounting unit needs to be chosen and this in turn raises the twin questions of the conversion factors and the routes to be used to express a natural unit of each type of fuel in terms of the common acounting unit.

35. While the mass of coal produced is a fairly unambiguous fact when expressed in tons, it can become a very subjective statistic when expressed in terms of oil equivalent (or even when expressed in terms of coal equivalent) depending on the convention one adopts when making this conversion. Even when expressed in terms of something more apparently objective, such as teracalories or, in accordance with the SI system 13/ terajoules, the apparent objectivity may be more subjective than would at first be expected. Coal is a far from homogeneous commodity in any country and the energy content of a ton of coal may vary quite considerably from one seam to another and certainly from one mine to another. For some purposes, such as drawing a broad brush picture of the energy situation or outlook there may be no reason to depart from the simple arithmetical proposition that all tons of coal are of equal energy value. If in order to express these in terms of terajoules, the route taken consists of using a single average figure for the energy content of a ton of coal, then the arithmetic is straightforward, but the true energy content of the coal will of course depend upon the mix of grades of coal within the total. This terajoule total is not as objective a statistic as the original tonnage of coal. This is a particular example of the distinction between an accounting unit on the one hand and the route to that accounting unit on the other. We shall return to the question of units, conversion factors and routes later.

C. Reasons for needing energy statistics

36. Attention has already been drawn to the shifts in emphasis by energy analysts and to the new areas of interest to those concerned with energy policy that have taken place largely since the early seventies. Before proceeding further it is useful to consider once more some of the statistical implications of some of the economic and policy problems now in the forefront of public debate. These may be summarized as follows:

Topic	Statistical problems
(a) Depletion of fossil fuel reserves	Consistency between the concepts used for defining "reserves" and "production"
	Relation between energy and non-energy uses
(b) Future demand for energy	Meanings of "demand"
	Relationship between commercial and non-commercial fuels
	Industrial autogeneration
	Comparability of energy uses and industrial output. Substitution of fossil fuel/other sources for animate energy in transport, pumping and other uses
(c) Role of nuclear generation of electricity	Treatment of nuclear fuels and nuclear energy in an energy balance
(d) Scope for energy saving	Measurement of energy effectively used by different purposes, processes and products
(e) Direct and indirect effects of price changes for energy sources	Relationship between value data on energy (and other goods and services) in input/output tables and physical data on energy flows in energy balances
(f) Environmental protection	Treatment of heat emissions
(g) Combined heat and power generation	Relationship between energy inputs and joint outputs

(h) Impact of renewable energy sources	Measurement of equivalent primary energy input
(i) Import dependence	Alternative concepts of consumption and import dependence
	Visible and invisible trade in energy

37. This list could be extended but as it stands it helps to focus attention on a range of statistical problems that need to be resolved when setting up an integrated system of energy statistics. One may even ask whether a single system can be capable of meeting all these varied needs and many other needs as well. A negative answer would be a counsel of despair, in that it is precisely the proliferation of energy data systems, accounting conventions, units and classifications that has produced the confusion that now so easily occurs when attempting to relate the assessments of different energy analysts or the recommendations of different policy advisers.

38. There will of course be a need for other types of energy data for special analysis and particular other purposes that will not fit neatly into an overall basic data system, but the data used in such analysis ought in principle to be compatible with and - if the data in question concern energy flows or stocks - should be derivable from the data that are covered by the basic system of energy accounts, balances and satellite tables.

D. Costs and benefits of statistical data

39. There must of course be a balance (in the cost/benefit sense) between the completeness, accuracy and timeliness of a data system and the cost of establishing and operating it, and the cost of errors in policy decisions that are based on a less than perfect data system. As we shall see later when considering "useful energy" (the energy effectively converted into useful heat, light or motive power by final energy users), it is easy to provide rows and columns in an overall energy balance that would, if completed, show information of great interest to an important class of analyst, but the cost of gathering all the data required from all categories of final energy user with the accuracy needed if the data are to be of the same quality as that of other data in the same balance, could be very expensive. The distinction has to be made between "need to have" and "nice to know" data.

40. The cost of data collection, validation and analysis ought not to exceed the benefit derived from the difference in decisions made with the data compared with the decisions that would be made without the data. This principle is more easily stated than implemented. It is not easy to specify all the decisions that are or will be materially influenced by the presence or absence of a particular piece of statistical data. It is even more difficult to assess the longer run benefits or costs of particular decisions. This problem is compounded by the wide range of possible spatial, institutional or social boundaries one could define beyond which one would ignore costs and benefits. Despite all these practical difficulties, the underlying principle should nevertheless be borne in mind.

E. Quality of data

41. Another desideratum that is more easily stated than implemented is quality labelling of energy (and other) statistics. This problem has been discussed from time to time in different statistical fields. It is relatively easy to assign margins of error and associated levels of probability to estimates derived from properly designed sample surveys, and something broadly similar though necessarily less satisfactory, can be done with estimates derived from panel surveys and partial censuses (including incomplete response to what was intended to be a complete census).

42. In principle, recorded figures for stocks or flows of inputs to or outputs from the energy industries themselves and their major industrial customers (such as the iron and steel industry or chemicals industry) should be fairly accurate, but as we shall see in the next chapter, much can depend on the definition one gives to a particular stock or flow. Two statistics on the same subject may score high points for accuracy but low points for comparability.

43. The real difficulties present themselves when a full supply and use account is constructed for any one source of energy, and a fortiori when two or more such accounts are integrated into an overall energy balance. Such balances, whether for separate energy sources or for all sources within a defined energy system, include interdependent elements of widely differing levels of reliability and it may become almost impossible to assign confidence margins to aggregated data. Such difficulties should not, however, be regarded as insurmountable barriers to progress but as obstacles to be crossed. Even if the separate margins of confidence for each component of an aggregate cannot be assessed, the sensitivity of aggregates to assumed errors in their main components deserves investigation. Such investigation could throw valuable light on the reliability of calculated rates of change and percentage shares in totals.

RECOMMENDATION:

(4) National and international statistical offices should consider seriously attempting to assess the sensitivity of each major published aggregate in their energy statistics to errors of plus or minus (say) 5 or 10% in the less reliable components of such aggregates.

F. Essential features of energy balances

44. Any system of energy accounts should be based firmly on the first law of thermodynamics which states that the amount of energy within any closed system is fixed and can be neither increased nor diminished unless energy is brought into or sent out from that system. An energy balance for an individual source of energy (e.g. coal), or for a group of closely related energy sources (e.g. petroleum products), is an energy commodity balance. Such a balance will show the origins (production, imports, stock fall) and uses (exports, stock rise, input for transformation into another energy source, non-energy use, final energy consumption), measured at least in the original units (e.g. tons) appropriate to the energy source in question. It may also, or alternatively, be based on an energy unit (e.g. kilocalorie or terajoule). An energy commodity balance will not however show the secondary energy output (e.g. electricity) that results from the transformation of the source to which that particular commodity balance relates.

So far as that balance goes, transformation is one among other uses of the energy source in question. The most convenient order in which to place the various elements of the balance is considered in chapter V. The compilation of basic data is considered in more detail in annex VI.

45. An over-all energy balance is a supply and use account that shows (ideally in a single table) the origins and uses of all sources of energy used in a given country during the year (or maybe another time period). Such a balance must necessarily express all forms of energy in a common accounting unit, and will show the relationship between the inputs to and the outputs from the energy transformation industries. In chapter V it will be shown that the most convenient order in which to place the various rows is not exactly the same, as that most suitable for an energy commodity balance. The same chapter considers alternative units of account.

46. Such a system should be as complete as possible within whatever external boundary has been defined. All stocks and flows of existing forms of energy should in principle be accounted for and known future sources of energy such as solar, tidal, wave, wind, and biomass should be capable of being recorded in the system without changing the rules. For policy purposes however a less than complete balance may be better than no balance at all. The system should in principle be free from double-counting while showing all relevant types of supplies and uses of energy. The system should show explicitly flows of exhaust heat to the environment. In due course, the system should be able to show flows of energy from the environment with the introduction and spread of heat pumps. The system should also in principle be conceptually compatible with other economic analyses such as national accounts and more particularly input/output tables.

47. These considerations to some extent oversimplify the picture. While double-counting is to be avoided to the extent that it misleads and confuses, it is to be sought to the extent that it helps better understanding of flows of different kinds of energy within or between different parts of the economy (e.g. flows in each direction between refineries and associated chemical plants, recycling of salvaged lubricants by oil refineries). Whilst full conceptual comparability between energy and other economic statistics may not always be possible, for the very good reason that two types of data may be required for quite different purposes, the conceptual relationship between the two types of information should be made clear (e.g. through some kind of transition table).

48. One or more of a number of accounting units may be used - and we return to this aspect later - but great confusion and much waste of readers' time can be caused by insufficient information being given in published energy statistics on the units that are used.

RECOMMMENDATION:

(5) National and international statistical offices, and bodies that advise them or undertake work for them, should always define clearly the accounting units or presentation units employed in published analysis. The conversion factors and the route used to convert original physical units into the chosen common accounting unit or units should also be stated, or a readily available published source where they may be found should be cited. It should also be made clear whether energy units are defined on a gross or net calorific basis (see chap. IV, sect. G).

49. Whatever the actual format (in the sense of the order in which particular stocks, flows, origins and uses of energy are shown), an overall energy balance should show at least two and (ideally three) levels of measurement. Firstly there are the primary energy sources, which may be delivered either to the energy transformation industries (e.g. oil refineries, power stations, gas manufacturers, and solid fuel manufacturers) or to final energy users (inside or outside the country in question). Conventionally these sources and flows are often designated as "primary fuel input". 14/ Secondly there are the energy sources, whether primary or secondary, that are supplied to final energy users. ("Final energy users" means all users outside the industries that produce or transform primary sources of energy - called collectively the "energy industries", since the production of primary or secondary sources of energy is their principal activity.) 15/ These flows collectively are designated as "heat supplied". A more general term would be "energy supplied". This latter flow does not indicate how much heat, light or mechanical work is derived by final energy users from this supply of energy. This third level of measurement is "useful energy" but it is very difficult to measure with sufficient accuracy for inclusion as a regular section of an overall energy balance. (We return to this problem in chap. VI.) 16/

III. BOUNDARY PROBLEMS

A. General

50. In chapter II (para. 36) a number of topics in energy policy and analysis were listed together with a number of the statistical problems to which consideration of those topics gives rise. In this chapter we shall examine more fully what those problems are, the choices which they open up and the interdependence between possible solutions and the practical questions for which the statistical data are needed. As has been pointed out already, frequently there is not a unique statistical practice that will meet all needs. At the same time, it is necessary to attempt to seek agreement on a basic and fairly complete accounting framework as a standard, which may need to be supplemented or departed from in clearly acknowledged ways for particular and clearly recognized purposes.

51. The following sections consider two broad classes of boundary problem. Firstly there are the possible boundaries of the energy data system as a whole. Secondly there are some boundary problems between a number of stocks and flows within the overall data system. The relationship between visible and invisible trade in energy is discussed in chapter IV, section F.

B. The system boundary

1. Energy and non-energy flows

52. Some primary energy sources (e.g. coal, natural gas) and some derived energy sources (e.g. naphtha) may be used either as fuels or as feedstocks to petrochemicals. Some petroleum products (e.g. bitumen, lubricants and waxes) are never ordinarily used as fuels. Petroleum coke is commonly used as a non-energy raw material for industry, but in some countries is also used as refinery fuel. Customarily, in most existing energy balances (see chap. V below) the non-energy use of petroleum products (and sometimes, natural gas) is explicitly accounted for and distinguished from energy use of primary and secondary energy sources.

53. Alas, this treatment does not dispose of the problem completely. Most of the chemical processes involving hydrocarbon feedstock yield fuel by-products and most of these are used to produce part of the heat needed by these processes. Further, in quite another part of the chemical industry, such as in the manufacture of sulphuric and nitric acid, heat is released by exothermic chemical processes that do not have any heat-input at all. Some of this byproduct heat is captured and used to raise steam to produce either shaft motive power for direct use or through electricity generation as a means of distributing motive power elsewhere in the plant, or to supply hot steam as a medium for distributing process or space heat within the plant. Part of the coke in blast furnaces acts as a chemical feedstock rather than as a fuel. Electricity used for electrolysis could also be said to be a non-energy use of an energy source, unless one widens the concept of energy to include all chemical energy.

54. If an energy balance seeks to cover all forms of energy supply and use, then arguably it should attempt to include all these forms of energy that are derived from what are customarily regarded as non-energy uses of energy sources, or as non-energy sources. If, alternatively, an energy balance seeks to account only for

the uses made of primary and secondary energy sources, then it should ignore energy derived from other than recorded energy uses of energy sources: when the accounting framework provided by an energy balance is used as a basis for forecasting exercises, or as a means for presenting the results of forecasts, the more narrowly "energetic" figures will reflect implicitly changes through time in the supply and use of unrecorded energy sources.

RECOMMENDATION:

(6) Energy balances should cover only all the supplies and uses of primary and secondary energy sources, showing clearly the non-energy use of such sources.

2. Commercial and non-commercial energy sources

55. Non-commercial sources of energy are ordinarily thought of in the first place as covering such things as firewood, sugar-cane waste (bagasse) and dried animal manure. These products - some of which do enter commercial trade in the cities and towns of some developing countries - together with the motive power provided by draught animals and by man are of significance for energy balances because they represent not only a large part of total energy consumption in such countries, but also a potential demand for fossil fuels or electricity from the commercial supply system in future years. On that criterion, however, there are other important non-commercial sources of energy (non-commercial in the sense that they do not pass through the market place) and these sources are more important in the more developed than in the less developed parts of the world.

56. One example of this type is the auto-produced heat, whether from fuel by-products in petrochemical processes or from non-fuel exothermic heat captured and used elsewhere in the chemical industry. Another is the use of waste materials in the timber and paper industries and the exhaust heat recovered from coke ovens and blast furnaces. If an energy balance is to record all energy flows it ought, arguably, to include these flows. On the other hand since these flows of recovered energy are joint products with the main output of the industries in question, this energy represents a decrement in the demand for (or an increment in the supply of) commercial fuels only to the extent that such recovered heat is delivered to users outside the industry that produces it.

57. Another case is the energy captured by solar frames, wind motors and heat pumps by industry, commerce or private citizens. To the extent that such energy displaces energy previously bought on the market, it is a decrement highly relevant to projections of future demands. To the extent that such energy constitutes an additional supply to the user, one could argue that it represents a conditional increment in future demand from the market place: if the energy user becomes accustomed to his higher level of energy use, he may demand supplies from the commercial market when his auto-production device is not functioning. At the same time, such phenomena will be reflected (after a time delay) in the time trend of demand and do not necessarily need separate quantification.

58. This argument, based on decrements in the future demand for commercial energy could be pushed a stage further. The installation of better insulation in roofs, walls and windows of buildings results in a decrement in demand for energy sources from the commercial supply system. It would however be following a principle

rather too rigorously if one were to enter the national energy not obtained from the market as representing the energy obtained from the improved insulation. Yet it is true that without this better insulation, or the solar frames, windmotors and heat pumps, the demand for commercial fuels would be greater.

59. There are two cases in which the substitution principle (i.e., representing auto-produced energy as a purchase that would be made from the market if the auto-production did not occur) is followed in some balances. One is the production of methane, or other low grade gas from waste and the burning of urban refuse to produce heat and/or electricity. Another is the case of where manufacturing industry generates its own electricity, often jointly with the production of process heat. The simplest treatment of this latter case would be to record as "final energy use" the fuels purchased by the industries concerned, and to regard the uses made of those fuels as wholly internal to the industry. Another possible treatment would be to regard only such auto-produced electricity as is actually sold outside the industry that produces it. A more problematical instance is where large amounts of hydroelectricity are produced by industry for its own use as its main or only source of energy. If such electricity is not recorded in the balance for a country such as Norway, then the output of some major industries (e.g. aluminium and fertilizers) will appear to have no energy input even though the commodities they produce are, of their nature, energy-intensive. Rather similarly, sugar mills may derive all their process heat and steam requirements by burning bagasse. Chapter VI considers the question of what may be desirable in the way of data on the whole range of purposes to which energy is put within final use sectors, and one way of treating own-produced hydroelectricity would be to include in, or as a satellite table to, the overall energy balance a detailed analysis of auto-production (and recovery) of energy within final energy use sectors.

60. In most national and international balances, however, all auto-produced electricity is treated as if it was purchased as electricity and the estimated fuel input to its generation is deducted from industrial fuel use and allocated instead to an enlarged electricity generation industry (usually distinguishing industrial power plants from public supply power plants). This treatment is justified on the ground that electricity generation could, at least theoretically, be wholly delivered by the industrial power stations to the public supply distribution network. The assessment of the fuel input to the electricity output of combined heat and power stations (which is a particular case of attempting to apportion fuel inputs between two joint products) poses a difficult problem which is explored further in chapter V.

61. This treatment of industrial autogeneration has the effect of reducing the total level of energy supplied to the industrial sector in the final energy consumption section of an energy balance: the primary fuel input to generation of electricity (with or without joint production of process heat) is replaced as an input by the energy value of the electricity generated. (This is the opposite of the more common replacement, statistically speaking, of electricity output by the primary fuel input notionally needed to generate that electricity in the case of nuclear and hydroelectricity - see chap. IV.)

62. There may be conceptual options in the case of energy sources not passing explicitly through the market in the more developed countries. In the case of the less developed countries, however, the exclusion of non-commercial fuels would exclude up to half or more of estimated total inanimate energy consumption. The energy provided by animals and humans (animate energy) for transport, cultivation,

food gathering and processing and for fuel gathering - i.e., for tasks that in more developed countries would be largely or wholly accomplished with the help of mechanical, electrical or other energy-consuming devices - represents another and probably even more important segment of the energy supply and use in developing countries. Data on such non-commercial energy sources are sparse even in the case of those sources (e.g. firewood) that pass in significant quantities through scattered commercial markets, but all these flows, whether or not commercial in the ordinary sense, should in principle be covered when attempting to construct energy balances for developing countries. As previously pointed out, such sources of energy represent potential demand for conventional commercial energy sources and/or for non-conventional sources such as biogas, wind or water power.

RECOMMENDATION:

(7) (a) An overall energy balance should cover all flows of energy including the so-called "non-commercial" sources. Coverage of such sources should be as extensive as possible. When such sources are known to be important but little data exist, such steps as sample surveys should be instituted to improve the amount and quality of data.

(b) Autogeneration of electricity from purchased fuels, with or without the joint production of heat, should be treated as part of the transformation sector.

(c) Autogeneration from industry's own hydropower should be treated as primary production of electricity.

(d) Steam or hot water produced by the combustion of industrial (or urban) wastes or by exothermic or other heat recovered within industry, should be recorded as primary production.

(e) Each method of electricity generation contributing a significant amount of the total supply of electricity should be assigned a separate row in an energy balance.

3. Energy industries and other industries

63. The preceding discussion and recommendations regarding energy and non-energy uses of energy sources, and commercial and other sources of energy, has already covered some aspects of this boundary problem. Thus the generation of heat energy in the chemical industry or of gas at blast furnaces or of electricity and heat in other parts of industry does not of necessity require that the whole of such derived energy producing activities are included in the transformation section of an energy balance. One possible treatment would be to consider only such derived energy as is sold outside the producing industry as part of the transformation sector in an overall balance. This would be rather restrictive, and the preceding recommendations were based on a more comprehensive view of energy supplies and uses.

64. There is a slightly different boundary problem in the case of petroleum refineries and the petrochemical industry. It is not uncommon for large companies to operate in both fields and to seek technical economies and flexibility by running integrated plants that combine the whole range of activities from refining crude oil to the production of finished plastic materials. The flows of

hydrocarbon-based materials and their derivatives in such a plant can be very complex, and particular net flows may not be easy to categorize or quantify. According to one view, since it is petrochemical technology that is the basis of the entire range of activities, any subdivision into oil refining on the one hand and petrochemicals on the other, is artificial and causes more statistical problems than it solves.

65. On the other hand there is a clear distinction on the output side between the energy-source petroleum products and the numerous plastic and other chemical products that are not intended to be sources of energy. Existing international economic classifications are based on recognizable differences between the characteristic products of different industrial activities. Despite the very real data problems that can sometimes occur in obtaining complete information on all the truly energetic flows that (it is recommended) should be covered in an energy balance, the argument for treating not only refining, but also all the other activities of the petroleum and related chemicals industry, as part of the energy industry is not convincing. The industrial activities to be included can most conveniently be delimited by stating the commodities to be covered.

RECOMMENDATION:

(8) (a) Energy balances should only cover all the hydrocarbon commodities as defined by a list either embodied in or accompanying the balance table (see chap. V).

(b) The problems of defining and obtaining more complete data on the gross and net energy flows between oil refineries on the one hand and petrochemical plants on the other should be investigated more fully. Satellite tables to an overall energy balance could usefully show as fully as possible at least the more important flows of energy by-products (and recovered heat) within the major branches of the chemical industry.

4. Energy production and distribution

66. Production of energy (or, strictly speaking, production of an energy source) may be defined for the present purpose as follows:

(a) For primary energy sources, it is the separation of a primary energy source from its reserve or basic stock in the case of fossil and fissile fuels and geothermal heat, and the capture of "flux" energy from the flows of solar energy and of kinetic energy from the winds and moving water. Nuclear energy is amenable to at least three different treatments to which we return later. For completeness of the present working definition, nuclear fuel is broadly analogous to fossil fuel;

(b) For secondary energy sources, production is the provision of an output of that source after transformation from one or more primary and/or secondary sources. Distribution of energy is the transport or transmission within a country by road, rail or water transport (or less usually, air transport) or by pipeline or power cable of energy from production to transformation or other uses.

67. These distinctions may seem pedantic and self-evident, but it is important to be aware of them because of their relevance to the consistency (or

inconsistency) 17/ of the definition of the boundary within which stocks are to be or can readily be measured, and both within which and across which all flows are to be measured, in a comprehensive system of energy statistics. (The distinctions are also highly relevant to consideration of the definitions of some particular flows and whether those flows should or should not be included in an energy data system. This part of the discussion will be taken up in the next section.)

68. Inconsistency in applying the distinction between production and distribution is sometimes almost inevitable because the nature of each energy source imposes constraints on storage and on particular methods of distribution. Solid fuels can, but rarely do, travel by pipeline; crude oil usually travels by pipeline or by water-borne tankers, as do liquid petroleum products, although road or rail tankers are also used for smaller consignments; gases normally travel by pipeline but are in some cases transported in liquid form by sea, road or rail tanker; electricity is always transmitted by cable. It follows that users, whether intermediate (in the energy sense, i.e. the transformation industries) or final (again in the energy sense, final energy users in the agricultural, manufacturing, transport, distribution, other service or domestic sectors) are connected in a very specific way to suppliers of energy sources transmitted by pipe or by cable, but may be insulated by an independent distribution service with its own transport and storage facilities in the cases of solid fuels, some gases and most petroleum products.

69. From this and the fact that electricity and most gas is not storable outside the producing industries, it follows that the flows to final users can more easily be recorded as deliveries than consumption, and figures on stock changes are more easily obtained for the energy industries than for final energy users. Stock changes for storable fuels may intervene at two or more stages between production and final use, so that production, deliveries, receipts and consumption may all differ from each other.

RECOMMENDATION:

(9) Published energy balances, whether for particular energy sources or for all energy sources in a single table, should always make clear whether flows represent production, deliveries, receipts or consumption; and the coverage of stock changes (and stock levels) should make clear whether or not they cover producers, importers, transformers, distributors and final users' stocks.

C. Boundaries between flows and stocks

1. Production and waste

70. The definition of "production" in the preceding section is independent of what happens to what is produced. The concept of production has an existence in its own right. It reflects (when expressed per unit of time) the rate at which a finite reserve or resource is being depleted, and it reflects at the same time the physical flow directly attributable to (among other factors) the stock of fixed investment in machinery and equipment specifically installed to make that production possible.

71. These are two important aspects of production and there is no doubt that for relating production either to reserves of energy sources or to investment in energy

getting equipment, "production" must be defined in the above purist way. However, when entering "production" in a complete balance, there must be consistency in the coverage of supplies and uses of energy. This means that if, as was recommended above, an overall energy balance only covers commercial forms of energy, then, "production" should be defined as covering only marketable production.

72. Coal, crude petroleum or natural gas produced during the exploration and development stages of preparation for full-scale commercial production may be marketable so far as the quality and other characteristics of the extracted energy source are concerned. The electricity generated during the pre-commissioning stage of a newly completed power station is certainly marketable production. Nevertheless such production may not all actually be supplied to the users who are to be included in an energy balance.

73. There are further problems. After extraction from a pit, coal is sorted and cleaned. Depending on the size and other characteristics of coal currently defined as commercially marketable, so the quantity rejected as unmarketable will be determined, and this quantity will be put on a waste heap. At that point in time and for maybe many years afterwards, that judgement will hold good. It may happen at some future point of time when coal and other fuels become scarcer (or because incomes of consumers fall sharply in a major economic depression) that coal hitherto rejected as unmarketable is later considered as marketable.

74. If the unmarketable coal was excluded from production statistics when it was extracted and thus excluded from the supply, clearly the coal in the waste heap stock later judged marketable must be treated as if it has been produced for the first time, and must not be treated as a withdrawal from stock.

75. In this example, the change in the marketable status of the coal presumably could not have been foreseen with certainty and, if this change had been assigned a probability when the coal was first produced, that probability would have been extremely low. Now, in the early eighties, a higher probability of future economic use as fuel of some kind could be assigned to coal currently being rejected as unmarketable.

76. Nevertheless to define production so as to include reject coal would result in an ever growing stock of currently unusable coal. It should be noted, however, that defining production as excluding reject coal may cause an inconsistency between production (viewed as the rate of depletion of reserves) and the level of reserves to the extent that the actual average content of usable coal per ton of material extracted differs from that assumed when the level of reserves is estimated.

RECOMMENDATION:

(10) Production of coal should be defined as extraction from the ground less waste and screenings plus recoveries from the waste heap.

77. A rather similar conceptual problem occurs with the flaring of methane associated with crude oil. This is, statistically speaking, a more immediate problem. Although such flaring has occurred on a significant scale in the Middle East and elsewhere for several decades, only since the events of 1973 have alternative uses for flared gases become an economic possibility. In the case of North West European Continental Shelf oil and the associated gas, the choice

presented itself, on the one hand of maximizing production of crude petroleum together with that part of the associated gas that could safely be brought ashore by pipeline or tanker (namely ethane, propane, butane and condensates of C^5 and above), which meant flaring the methane at the production platforms; or, on the other hand of delaying bringing the crude oil ashore until a gas-gathering pipeline system had been laid. The Government of the United Kingdom decided to opt for the former course of action initially.

78. This has meant two things. Firstly, production of highly marketable gas is being - or has been - flared. Secondly, the intention from the outset has been to pipe the methane ashore in the future if possible. In contrast to the case of reject coal, the future intention regarding the reject gas has been known from the start of crude oil production in the North Sea. In this case, therefore, the production of associated gas is part of marketable production even though it has been neither marketed nor put into stock. It has been burnt, and this contributed (very small) amounts of heat to the environment (see below).

RECOMMENDATION:

(11) All production of associated gas should be treated as part of production of gas, and that part that is flared should be so described. In this way, the change in the output of the production of oil and gas will not show a "step-change" when the use of part of the gas changes. By analogy, total production of coke oven gas and blast furnace gas should be recorded in an energy balance, with amounts bled to waste shown as losses.

2. Production and stocks

79. As an alternative to bringing ashore or flaring associated gas, it may be reinjected into the field from whence it came. The same may be done with non-associated gas. In the first case, the purpose may be to maintain the pressure on the oil in the field so that a higher proportion of the oil may be extracted. The intention may (or may not) also be to re-extract the gas later for use ashore. In the case of reinjected gas at gas fields, the purpose is to retain the reinjected gas for later extraction and use ashore.

80. This reinjection is clearly a case of stock-building in the wholly or primarily gas fields. In the case of the associated gas in the oil fields however, there is no certainty that the gas will be re-extracted and hence the reinjected gas could be treated statistically either as a stock-build, or as a use "injection" of "production", or it could be excluded from "production". The most informative and least troublesome treatment would be the second. On balance, the simplest convention for energy balances would be to exclude all reinjection of gas. (As we shall see later, there maybe a case for showing reinjection in the oil and gas industry's own detailed statistics.)

RECOMMENDATION:

(12) All production of gas, either associated or non-associated with crude petroleum, should be recorded net of injection of gas into gas or oil fields. If injected gas is later extracted for a second time, it should be treated as produced then for the first time.

3. Stocks, consumption and waste

81. Nuclear fuels and their derivatives pose problems very similar to those that would be raised by coal if all existing commercial boilers, because of, for example, the materials used in their construction, were able to burn only a part of the combustible fuel fed to them, and if the part-burnt coal were to be recovered from the ash and reprocessed for feeding to the same or another boiler later, and if this recycling were to be repeated three or more times. Such a procedure would correspond to what happens, broadly speaking, with most existing nuclear reactors (known as "thermal" reactors). The analogy may be carried a stage further by supposing that the treated ash from which no further combustible fuel can be recovered for any commercial boiler now existing, could nevertheless be used as a source of heat in a new process that was known to work but not yet operational on a commercial basis: the waste from current technology would be the fuel for a new technology. The new generation of nuclear reactors that may one day make this possible are the fast or breeder reactors. 18/

82. These nuclear processes raise two statistical problems in the area of concepts. Firstly, we have an input to a transformation process that is only partly consumed during any one accounting period, so that the difference between the input of the primary energy source (nuclear fuel) and the output of the derived energy source (heat or electricity or both) does not represent a process loss except to an extent that is very small compared with the amount of energy stored in the input. Secondly, we have as one component of that difference a residue that cannot be used by that particular transformation process or by any other process currently operating commercially. Thus so far as the current transformation process is concerned, this residue represents waste. Yet it is fairly certain (or at least highly probable) that this waste will become an input to a new process within the next 5 to 10 years.

83. It is clear that the energy balance accounting framework ought to be able to show separately that part of nuclear fuel input during a year that is used up within that period, the part that is recoverable for recycling during subsequent accounting periods, and the part that is recoverable but is not capable of recycling for heat-release by current commercial nuclear processes. We shall return to how this can be done in an overall energy balance later in this report.

84. There is a third statistical problem raised by nuclear power. A consequence of the very low ratio between the energy produced during a year and the energy stored up in the nuclear fuel that passes through a reactor during the same year is that the total quantity of energy in the fuel contained in a reactor core is very large indeed compared with its annual heat release.

85. This large store of energy, only a very small part of which is "accessed" during a single accounting period, is more like "working capital" than a simple stock of fuel. Further, during the several years of the build-up period of a nuclear power programme, the quantities of stored energy represented by the initial loading of fuel into the reactor cores of new nuclear stations are very large compared with the quantities of stored energy in the part-used fuel removed from operational reactors. There is therefore a need to provide in an overall energy balance for appropriate sub-divisions of the category stock change. We shall return to this later.

IV. ACCOUNTING LEVELS AND ACCOUNTING UNITS

A. General

86. Chapter II ended with a short description of the three levels of measurement which, ideally, would be shown in an overall energy balance. To recapitulate, these were:

(a) Primary energy and equivalents: the supplies from production, stock withdrawal or net imports of primary energy, and supplies - other than from production - of their equivalents. (Primary energy equivalents are the flows from net trade in or stocks of secondary sources of energy. These latter two flows, one or both of which may be negative, are equivalent to flows of primary energy so far as the country in question is concerned.);

(b) Energy supplied: the deliveries of primary energy from production, stocks or net imports, plus secondary energy from transformation, stocks or net imports, to final energy users;

(c) Useful energy: the energy that is actually converted into useful heat or work obtained by final energy users from the primary and secondary energy sources delivered to them, with a given stock of energy-using equipment, appliances and processes and a given mode of operation of these facilities.

87. The same chapter defined the "primary energy input" or "fossil fuel equivalent" of a secondary energy source as the amount of primary energy that would, in fact or on a stated assumption, be required as the direct energy input to the transformation process that has a particular secondary energy source (e.g. electricity) as its output. This present chapter explores in more detail some particular cases of the application and interpretation of this concept.

B. Primary energy input to final demand

88. This concept is readily applicable to the classical transformation industries, namely thermal power stations, oil refineries, coke ovens and gas manufacturing plants, although (as pointed out in chap. II) the concept is usually applied only to electricity, and it illustrates that final energy users are in effect expressing a demand for the total amount of primary energy sources needed to meet their requirements for secondary sources (thereby providing automatically for the process losses in the energy transformation and distribution industries).

89. It has sometimes been argued that final demand for energy should only be recorded either in this way or as useful energy. 19/ According to this line of reasoning an analysis of final energy use in terms of energy supplied, particularly if used for making or reporting forecasts, wrongly implies that x units of electricity may be substituted for x units of any other energy source, and that such arithmetical substitution would leave the total level of energy use by the sector in question (e.g. manufacturing industry), and by the economy as a whole, unaltered. Substitution of electricity for or by any energy source other than electricity implies in reality an exchange of 1 unit of electricity for about 3 units of any other source in terms of primary energy input, the proponents point out, and they maintain that only by recording electricity consumption in terms of

its primary fuel input can erroneous substitution be avoided when examining, for example, possible modifications to a forecast.

90. This argument is not very convincing in that an analysis of final energy use on this basis may lead to misinterpretation. The unsuspecting reader may think (wrongly) that 1:1 substitution between electricity and other energy sources leaves final users with the same total amount of energy. A more serious objection to showing final energy use only in terms of primary fuel input is that it pre-empts the whole of the exhaust heat from electricity generation and imputes it to the electricity using sectors: if waste heat recovery occurs at power stations through combined heat and power generation and if that heat is to be recorded as an energy source in the supplies part of the balance, we have an output of heat but no corresponding input attributable to that heat. 20/ Even in the absence of heat recovery - and indeed with heat recovery below 100% - the emission of waste heat to the environment ought in any event (one can argue) to be attributed to the industry from which it originates. 21/

91. Final energy users effectively demand the useful energy that their equipment and processes extract as useful heat, work or light from the energy sources delivered to them by the energy industries. Final users of energy will substitute one energy source for another at the rate of 1:1 on the basis of cost or convenience in having available the same quantity of useful energy. (This is an over-simplification but it is substantially true.) If - and it is at present a big if - complete data were available on useful energy, then this particular level of accounting would be the most important one for analysing past trends in energy use and for attempting to forecast, or for studying the implications of future patterns of energy consumption.

92. The lack of sufficient data on useful energy to carry an overall energy balance down to this level of consumption means that, for the present, energy supplied is the lowest level to which an overall balance generally can go. 22/ One effect of proceeding only thus far is to concentrate the recorded energy losses in the transformation industries and not to show the very large losses that occur when energy supplies are converted into useful energy (with efficiencies of 80% or more for electricity and of under 50% in many other uses). It does not however follow that an energy balance should only show the primary fuel input of energy sources delivered to final energy users. 23/

RECOMMENDATION:

(13) An energy balance should show all flows at each level that can be adequately recorded with existing data, so that the relationships between primary energy inputs to transformation, secondary energy outputs from transformation and transformation losses can be clearly seen. For some purposes, as a supplementary statistic, the primary fuel input equivalent of secondary energy sources delivered to final energy users is useful but may be difficult to estimate because of lack of sufficient data.

C. Primary energy input to nuclear and hydroelectricity

1. Nuclear electricity

93. The main physical characteristics of the process of nuclear fission are described in annex II. In all existing commercial nuclear stations the heat

released by the process has been converted into steam and then, through turbines, into electricity. In the future, nuclear heat may be applied more directly to a limited range of high-temperature industrial processes (such as metal extraction from ores) possibly followed by heat recovery for lower-temperature uses. Given present nuclear technology, the statistical problem is how to treat nuclear-based electricity in an energy balance.

94. Three approaches are possible. The most straightforward is to record the electricity output as such and to disregard the upstream energy inputs. The most common is to express the electricity produced 24/ in terms of the energy content of the fossil fuels that would be needed if the same amount of electricity had been generated in a conventional thermal power station. The third approach would be to quantify the amount of heat released by the reactors in nuclear power stations during the same period.

95. The second approach is based on the notion of a partial substitution model 25/ in which a choice is postulated between investing in a classical thermal station or in a nuclear station, and the outcome of the choice is assumed to depend essentially on the fossil fuel that would not be used if a nuclear station is built rather than a fossil fuel station. This is the economist's formulation of the problem in terms of the "opportunity cost" of a nuclear station.

96. This approach has much to commend it in the limited context of an investment decision that is about to be made particularly against a background of declining oil supply around the year 2000. Once made however and the further that decision recedes into the past, the less justification there might seem to be for retaining subsequently a historic opportunity cost. Whether or not this approach is retained after the decision, there are several unanswered questions: Which fossil fuel stations should be the basis for defining the efficiency factor to be applied to the assumed or forecast quantity of nuclear electricity? And should they be:

All existing classical thermal stations?

Existing base load stations? 26/

The new classical stations that would be built if the nuclear station is not built?

The existing station(s) that will be next closed down permanently after the nuclear station is built (and that it may be said to replace)?

The latest new classical fossil fuel station?

Two principles followed in current practice are to use either (for simplicity) the average thermal efficiency of all existing fossil fuel stations (SOEC do this), or of fossil fuel stations built in the same year as each nuclear station (the United Kingdom does this).

97. Any one of these bases illustrates the subjectivity of the assumption that defines the primary fuel input to an objectively measurable output of energy. A more objective concept of primary fuel input is desirable for more than the avoidance of this arbitrariness.

98. Three reasons for seeking a more rigorous treatment of the direct energy input to nuclear power are: the need to show the dependence of a country on imported energy sources; the need to provide for the likelihood in the future of direct industrial use of nuclear heat; and the anomaly of treating one particular clearly definable primary energy source (fissile material) quite differently from other broadly similar primary energy sources (fossil fuels). Whatever energy balance accounting framework is adopted, it must be sufficiently robust to accommodate, without compromising any important principle, nuclear and other new or renewable forms of energy on a consistent basis. We shall return to the detailed adaptation of existing balances to accommodate stocks and flows of nuclear fuels later. Such an adaptation is all the more necessary in view of the growth of foreign trade in nuclear fuel elements and in irradiated fuel.

99. Without pursuing further at this point the accounting details for the nuclear fuels, it is clear that the primary energy input to nuclear electricity is nuclear heat, that is to say the heat released by the nuclear fuel in the reactor core. This nuclear heat is available to be fed to turbo-electric generating sets or (maybe only 10 years hence) to high temperature industrial processes. The amount of heat released may be measurable directly or it may be calculable from known or assumed thermal efficiencies of generation nuclear power stations. Sweden and the United States of America use this last approach.

RECOMMENDATIONS:

(14) The primary energy input to nuclear electricity should in principle be defined as the heat released by reactors during the accounting period. In practice, a proxy for this may need to be used, namely the figure obtained by dividing generation of nuclear electricity by the average efficiency of all nuclear power stations.

2. Hydromechanical power

100. Hydromechanical power 27/ is of considerable importance in a number of the more developed countries 28/ and is potentially of great importance in many of the less developed countries. Because of the frequently very long distances between good sites for hydropower extraction and the markets for the products of industries that could use hydropower directly, it is usual for such power to be converted by water turbines into electricity rather than for it to be connected more directly to mechanical drives to machinery. (In the less developed countries, small scale hydro installations could be sited in scattered locations unsuitable for larger scale power stations.)

101. Thus hydro and nuclear energy have so far shared the characteristics of being almost entirely used for conversion into electricity before subsequent use as an energy source. As a result, hydroelectricity has been treated statistically in the same way as nuclear electricity in many if not most energy balances that include it, namely by recording either the heat value of the electricity output or the fossil fuel input that would be needed to produce the same amount of electricity in a classical thermal station. Some hydro countries impute to hydroelectricity a notional primary energy input on the basis of the mechanical efficiency of water turbines.

102. As with nuclear electricity, so with hydroelectricity the partial substitution model is defensible in the context of policy decisions that involve a real choice between an electricity generating station powered by fossil fuel, fissile fuel or hydromechanical power. But equally, as with nuclear electricity, this statistical treatment is of very doubtful value outside the confines of such problems. If this approach is used the question again arises of which class of fossil fuel stations should be regarded as the alternative to a hydrostation. In the case of hydro, the list of alternatives given in paragraph 96 needs to be extended by the addition of peak load stations (which could be gas turbine stations) since - unlike nuclear stations - hydropower can be easily started and stopped.

103. In countries where the existing amount of or potential for hydropower is great, the nuclear option may not be a very real one, and even if it is, one might argue for expressing the primary fuel equivalent of nuclear electricity in terms of the opportunity cost in hydropower rather than in terms of fossil fuel. In at least three such countries (Canada, New Zealand and Norway) the view is firmly taken that the alternative to cheap hydroelectricity is not fossil or fissile fuelled power stations but the direct combustion of solid or liquid fuels to produce most space and some process heating. There is another objection to the application of fossil fuel input to hydroelectricity. This is that such a notional output imputes to hydroelectricity some recoverable exhaust heat that does not exist. This misrepresentation is unacceptable in the context of energy conservation.

104. Strictly speaking, the primary energy input to hydroelectricity is the kinetic energy captured from the falling water. However, commercially produced hydropower is always in the form of electricity and no useful purpose in the context of energy balances is served by pursuing conceptual purity to the point of quantifying an energy flow that is not directly accessed commercially for any purpose other than electricity generation.

105. To record hydropower in a balance only as the electricity itself can however complicate the interpretation of comparisons of total primary energy between countries or through time, and it is customary in such comparisons to express the notional primary input to hydroelectricity in terms of its fossil fuel input equivalent. It is important to recognize however that such a procedure is a statistical device to remove one cause of variability in the comparison and is not a realistic adjustment to a uniform technology basis.

RECOMMENDATION:

(15) The primary energy input to hydroelectricity should be defined as the energy value of the electricity itself. The fossil fuel equivalent energy should be recorded as an additional statistic, using, for simplicity, either the average thermal efficiency of all classical thermal stations in the country concerned or a standard efficiency of (say) 35%.

D. Primary energy input to renewable sources of energy

106. "Renewable sources of energy" is a convenient label for the energy obtainable from biomass, solar radiation temperature differences that produce currents in deep oceans or that are found in rocks beneath the earth's surface, air pressure differences that produce winds, and natural or man-made differences in water levels.

107. Biomass consists of terrestial and aquatic vegetation and its residues (e.g. fuelwood, twigs, dead leaves, shells of wild-grown nuts) together with cultivated crops and their residues (e.g. cereal straw and seed-husks, jute sticks, bagasse). The term also covers livestock products and residues (e.g. tallow, dung) but not animal or human power used in agriculture or other productive activities. (Animate energy is discussed in the following section.) Biomass may be considered as one form of transformed solar energy.

108. All biomass is not necessarily renewable. Fuelwood may be "mined" from forests or woodlands that are all too often irreparably damaged or completely destroyed by the practice. Alternatively fuelwood may be cropped from well-managed wood lots that have been specially planted with fast-growing trees or bushes suitable for this purpose. Geothermal energy, too, may or may not be renewable depending on how deep one goes when defining the heat source and on how accurately one knows the boundaries of the hot-rock mass; and on whether the rate of heat extraction from a relatively isolated rock mass exceeds or is less than the rate at which that mass may receive heat from a connected larger geothermal heat source.

109. Solar radiation can be used in a number of ways. As mentioned above, it may be converted into organic material through large-scale cultivation of land or marine vegetation, and this material may then be fermented or distilled to produce alcohol, or be digested to produce combustible gas, or it may be dried for direct combustion. Alternatively solar radiation may be converted directly into electricity by solar cells, or it may be captured as heat in a solar frame and stored or used as hot water. With suitably elaborated equipment the sun's rays may be optically concentrated to produce temperatures high enough to evaporate special materials, such as freon, or to convert water into steam, for heat engines or even, at still higher temperatures, to apply more directly to industrial processes such as the extraction of metals from ores.

110. Pressure differences in water or air may be harnessed through suitable equipment that can intercept the energy in waterfalls, rivers and tides or respond to movements in the waves and the winds. The captured mechanical energy may be converted into electricity or, more simply, used to heat a suitable medium through compression. Unlike the electricity, such heat can be stored fairly readily.

111. By analogy with the theoretical treatment that could arguably be used (but not in fact recommended) for hydromechanical power, the primary fuel input to the new mechanical devices could be the energy captured by them. One might argue that this basis would fail to show the efficiency of the device in capturing all the primary energy theoretically accessible to it: friction and other unavoidable (and maybe avoidable) short-comings result in a loss of some of the kinetic energy in currents of water and air impinging on a collecting device.

112. Extending this notion to solar collectors, one could argue that the energy theoretically available is contained in the radiation falling upon the earth's atmosphere, and that man could reduce at least the man-made pollution and maybe go further and disperse at least some of the natural clouds in order to increase the proportion of energy that reaches the earth's surface. So to argue would however be somewhat pedantic and unhelpful. It would seem sufficient to regard solar heat collected as a measure of primary energy derived from solar radiation.

113. In the cases of fermentable, digestible and combustible materials, and of electricity produced more directly from solar radiation, the energy content of the

material, or of the electricity produced, would seem sufficient measures of the primary energy input from these methods of capturing solar energy.

114. All these proposals are of course to be qualified by what has been recommended in chapter III regarding the boundary between commercial and non-commercial forms of energy.

RECOMMENDATION:

(16) The primary energy corresponding to the so-called renewable sources of energy should be defined as follows and applied to the output of the first stage in an energy capturing process that yields a measurable output of heat, electrical or mechanical energy:

Solar:	Biomass	Heat output of the fermentation, distillation or combustion device
	Photovoltaic cell	Electrical energy output
	Other collecting device	Heat output of the device
Water and air:		Mechanical, heat or electrical output of the device
Geothermal and ocean thermal:		Heat output of capturing installation.

Economists and engineers working on the conversion efficiencies of these techniques may need in addition to assess the potentially recoverable energy that is awaiting capture. In the case of the basic primary sources of renewable energy (fuelwood and similar materials, crop and animal residues), the relevant quantity of primary energy is the estimated energy content of each such energy source.

115. Before leaving this part of the discussion it may be noted that there are yet other classification dichotomies besides those already considered (viz. commercial/non-commercial and renewable/non-renewable). One of these is conventional/non-conventional, where "conventional" consists of fossil fuels, large-scale hydro and geothermal; and (from a developed country's viewpoint) "non-conventional" covers all the renewable sources mentioned above, together with (at least in principle) animate energy sources. (It is no longer obvious where nuclear power should now be classified: it was non-conventional until it became fairly widespread in use. Some countries might now regard it as conventional at least in their own context. Further, from a developing country's viewpoint, fuelwood, charcoal and agricultural residues can hardly be regarded as non-conventional.) The other main dichotomy sometimes applied within the renewable group distinguishes between traditional/non-traditional sources. The traditional renewables are the biomass sources with (in principle) animate sources, and the non-traditional (also sometimes called the "new") renewables are biogas, solar, wind tidal, mini-hydro, ocean thermal and fuel alcohol. A four way classification that embraces all fuel types is: Commercial/Traditional/Non-Conventional/~~Annual.~~ Animate. (This is set out in annex ~~VI.~~ VII. Any such classification will need to be reviewed in

Corr.1

five to ten years time when judgements about what is non-conventional may have changed.)

E. Animal and human energy

116. In some parts of the world (e.g. South Asia) bullock carts and other animal transport provide a large proportion of the total land transport not only of agricultural materials and products but also of passengers and general merchandise. In the more mountainous parts of the region (e.g. Nepal), merchandise is very largely carried on the heads, backs and shoulders of men, women and children. In some of the flatter areas (e.g. Bangladesh), a very large part of passenger and goods transport even in the urban areas is provided by pedal-powered "trishaws" and by handcarts.

117. In other regions too (e.g. Africa), the fetching of water and the transport of goods to and from market is by the womenfolk and animals. In developing countries in all parts of the world, agricultural operations are carried out by the muscle-power of men and women with or without the help of buffalos or other animals. It follows from all these observations that any comprehensive account of energy supplies and uses in most developing countries will be seriously incomplete if it does not include estimates of the contribution of human and animal power to economic activity.

118. Before proceeding, there is a conceptual problem to be considered. The human muscle-power component of the energy input to economic activity represents, it is true, a potential demand for fossil fuels and/or electricity, but at the same time that muscle-power is the physical manifestation of labour as a factor of production. In National Accounts terms, labour is quantified as one of the income-shares of value-added (the other shares being rent, profits and interest). In that particular context, the input of human energy - whether as muscle-power or as brain-power - cannot be treated as an energy input instead or as well, except by regarding the unchanged figures as already representing the money value of the human energy.

119. It is none the less true that human muscle-power is one important energy source particularly in developing countries, and it ought not to be ignored, at least when assessing the likely future range of a developing country's demand for fossil and other energy sources. It is also illuminating (and salutary) to show the estimated extent of a country's current dependence on this particular form of animate energy. Animal muscle-power does not pose the same kind of conceptual problem and the estimated amount of such power should also be included in a developing country's energy accounts.

120. In principle, the amount of human brain-power absorbed by economic activities covered in the National Accounts should also be included, at least to the extent that such energy (and some of the associated purely physical effort) may be replaced by electronic devices that themselves make a demand on electricity (and hence on primary energy) supplies. In practice this particular element of energy demand seems scarcely worth trying to quantify separately.

121. The actual quantification of the amounts of a relevant human and animal muscle-power could be based on the estimated horsepower-hours (expressed in joules) of work performed in carrying, pulling or pushing loads of various sizes over

various distances on various types and gradients of terrain during a year. If the measurements needed for this approach can be made satisfactorily, then it is suggested that a more useful basis for estimation would be to express all the tasks that are to be performed in terms of the estimated quantities of fossil fuel that would be needed if those tasks were to be carried out using mechanically-powered vehicles and equipment. When making projections, one would of course have to make realistic assumptions about likely changes in the nature as well as in the volume of at least some of the various tasks (e.g., the likelihood of piped water replacing water-haulage over roads or tracks). The fossil fuel equivalent of current and future usage of animate energy is the statistic that would be of most practical value for the purposes of energy policy.

F. Primary fuel inputs to trade

122. Two sorts of problem arise in connection with foreign trade. One concerns visible trade in energy sources (including trade in non-energy products of the energy industries). The other concerns the wider question of invisible trade or embodied energy, namely the energy embodied in what are quite unambiguously non-energy products.

1. Visible energy trade

123. The convention generally followed in energy balances is to record import and exports of derived energy sources in the form in which the trade occurs. This is clear and straightforward, but one could argue that this treatment deals differently with exports on the one hand and inland consumption on the other. Earlier in this chapter, it has been accepted that the primary energy input in electricity generation can be a useful statistic as showing the primary energy resources needed in order to satisfy a given demand for electricity. That demand may be for the inland or the export market. The primary fuel input required is independent of the market that actually uses the electricity. One could therefore argue that if inland demand by final energy users can usefully be expressed in terms of the primary fuel input, then export demand can be similarly expressed.

124. If this principle is accepted, the question arises of whether imports of electricity ought not also, for consistency, to be expressed in primary fuel input terms. After all, imported electricity makes available to the importing country the high-grade energy it would otherwise have had to produce for itself from about three times as much primary energy input. 29/ Correspondingly, one could argue that if electricity exports are expressed on a primary energy input basis by the country making the export, then for international consistency the importing country ought to record its electricity imports on the same basis. On the other hand, using the primary energy input for imported electricity would impute to the importing country some recoverable waste heat, and using the primary energy input for exported electricity would reduce the quantity of waste heat theoretically recoverable by the exporting country.

125. Applying the same principle to foreign trade in petroleum products raises a more difficult question, and at the level of concept, it cannot be dismissed by the argument that was used earlier in this Manual to justify not applying the concept of primary fuel input to deliveries of petroleum products (namely that the total loss of energy in the refining process is very small compared with refinery output and is very much smaller proportionately compared with the 65% or so loss

in power stations). The difficulty arises because, whereas in the case of total inland consumption the whole range of petroleum products will probably occur in roughly the same proportions as those in which they are found in refinery output, imports will probably consist of a different limited range of petroleum products.

126. It is therefore not an easy matter to relate the two trade flows to the quantity of primary fuel (namely crude oil) that is needed for the exports or for the production of the imported products if they were not imported but were produced instead of the importing country. One cannot simply impute to each product the total quantity of crude oil that would be needed to produce it because, taking any one product (that probably represents only about 10% of the total quantity of crude) the imputed crude would amount to 10 times the quantity of that product. Proceeding thus for each product (each of which would represent somewhat different proportions of the total product yield of crude), one would count the same "maternal" crude several times over, and even then all the products ordinarily derivable from that quantity of crude would not occur in either the import or export trade flow for the country in question and the several derived quantities of maternal crude would probably not coincide in amount. 30/

127. A similar type of difficulty would occur with imports of coke or other solid fuel products, and with non-energy products of other primary energy sources. The conclusion of all these considerations is that trade flows are adequately and most simply acounted for by recording them in terms of the energy content of the energy sources or electricity that actually flows across boundaries.

RECOMMENDATION:

(17) Imports and exports of secondary sources of energy should be recorded for an overall energy balance in terms of the energy content of the fuels (or electricity) that actually flow across national frontiers. If a more detailed analysis is needed of the primary energy input to foreign trade, such an analysis can be made but it should be additional to, and not part of, the overall energy balance. Trade in non-energy products derived from primary energy sources (e.g. lubricants, carbon black, electrodes) should be recorded in the main energy balance.

2. Invisible energy trade

128. A statistical measure of a country's dependence upon (or independence of) foreign supplies of energy is the ratio of its energy imports to its inland use of energy. This ratio may be defined in various ways according to how one treats energy stock-changes, exports, bunkers and non-energy products. The point to be made at this stage of the discussion is that any such ratio that is defined solely in terms of stocks and flows of visible energy sources is likely to give an answer that is significantly different from one that also takes account of flows of invisible trade in energy, i.e. energy embodied in all commodities that are imported or exported.

129. To highlight this, consider a country that imports large amounts of metallic ores and exports aluminium and other metal products. That country will also require large quantities of high temperature heat and, unless it has suitable

supplies of hydropower, it must either produce or import considerable quantities of primary or secondary energy sources. If the same country now replaces its imports of ores by imports of semi-finished metal products but keeps its export level and mix unaltered, then it can reduce considerably its apparent consumption of energy from domestic or imported sources. This fall in the ratio of its visible imports to total use of energy fails to record that country's continued dependence on imported energy because its imports are now of energy embodied in the semi-finished metal products.

130. For certain detailed assessments of any country's overall energy supply and use, 'invisible' as well as 'visible' trade in energy needs to be taken into account but such analyses go beyond the limits of an overall energy balance table as envisaged in this Manual. 31/

RECOMMENDATION:

(18) International trade in embodied energy is a proper subject for a detailed assessment of energy problems. Nevertheless an overall energy balance should be constructed in the first place on the basis of, among other flows, only visible trade in energy sources.

G. Gross and net calorific values

131. Energy stored in fossil fuels may be measured at one or two levels. The gross calorific value (GCV) measures the total amount of heat that will be produced by combustion, but part of this heat will be locked up in the latent heat of evaporation (or condensation, depending on whether one considers the energy initially absorbed or the energy later given up) of any water present in the fuel before combustion together with water produced by the combustion process. The net calorific value (NCV) excludes this latent heat and is readily available from the combustion process for capture and use. The difference between GCV and NCV is of the order of 2.5% for anthracite, 3 to 7% for bituminous and sub-bituminous coals, 9 to 10% for lignite, 7 to 9% for liquid fuels and of the order of 10% for gases.

132. A strictly thermodynamic approach to energy accounting would require the evaluation of the GCV of all fuels up to the stage of energy supplied to final energy users. 32/ With the interests of conservation data in mind, it has already been recommended that the amount of waste heat emitted to the atmosphere by power stations and other energy transformers should be explicitly shown in an energy balance. 33/ Logically it follows that in principle the GCV should be used as the basis for evaluating the energy content of fossil fuels. 34/

133. At the practical level, however, an energy manager in a plant is not responsible for the loss of energy that he cannot access. Even though he must take delivery of the GCV in order to have access to the NCV (rather as one cannot ordinarily obtain fresh eggs without the shells, even though one throws the shells away), he can only be held accountable for the use or misuse of the NCV. With present technologies, the latent heat of condensation of water vapour cannot be recovered from exhaust gases - if these gases were to be cooled below a certain level, they would not rise out of a boiler chimney and the reduced air current would either reduce boiler efficiency or would call for the use of energy in

driving a fan to force the gases out of the chimney. Condensation of water will cause corrosion problems with SO^2 and other residues and will call for more costly stainless or other corrosion-resistent materials. Yet another practical consideration is that the natural moisture content of solid fuels depends greatly on the occurrence of a rainfall during transport and storage, so that NCV is a better indication of the energy effectively obtainable from combustible fuels when making comparisons through time and between countries (unless the moisture content of solid fuels is reduced to a standard level before GCV is measured).

134. A more pragmatic approach would start from the basis that the difference between GCV and NCV is relatively small in data about the past and present, and is very small compared with forecasting errors in assessment of the future. This difference is moreover a small part of the total amount of waste heat emitted to the atmosphere and for practical reasons only a part of this total heat loss can be recovered. It would, in principle, be possible to meet the needs of the thermo-dynamicists and environmental statisticians as well as those of the energy statisticians and other analysts by introducing a special row into the energy balance to show this particular cause of transformation losses. The balance could then show flows evaluated in GCV for supplies of fossil fuels up to and including the stage of inputs to the transformation industries, and evaluated in NCV for deliveries of all energy sources to final energy uses, with the difference between GCV and NCV for fossil fuels recorded in the new "losses" row. Such a device would however be a complication out of proportion to the gain in useful information in an energy balance, and the accuracy with which calorific values are measured for, and attributed to, each energy source may not justify such a presentational refinement.

135. The custom in several countries of measuring the energy value of gases in GCV does not necessarily mean that gases have to be recorded on the same basis in an overall energy balance. The SOEC (Luxembourg) has for long been publishing tables on gases in GCV while at the same time treating gases in terms of NCV in its overall energy balances. This seems on balance to be the more satisfactory basis for aggregating the potentially useable energy content of all energy sources taken together.

RECOMMENDATION:

(19) When expressing the energy content of primary and secondary fossil energy sources in terms of a common energy accounting unit, net calorific values (NCV) should be used in preference to gross calorific values (GCV). If and when recuperation of a significant part of the difference between GCV and NCV from exhaust gases becomes a practical possibility and seems likely to become a reality, this recommended basis may need to be reconsidered.

H. Accounting units

1. General

136. The four main energy sources - coal, petroleum, gas and electricity -, present a very good example of the recurrent problem in statistics of "adding up chalk and cheese". When one takes into account the products derived from coal (coke, coke oven gas, blast furnace gas, patent fuels etc.), the different forms of gas (natural gas and gas-works gas to mention the principal two), the various petroleum

products having a range of different characteristics, and the different ways in which electricity may be generated (by hydro, nuclear, or conventional thermal methods) the complexity of the adding-up problem becomes more evident. This complexity is compounded if one includes also the renewable energy sources (the wind, waves, hot rocks and solar energy.)

137. The original units in which fuels and electricity are most naturally measured, (tons for coal; tons, barrels or barrels per day for petroleum; kilowatt hours for electricity; and therms, calories, joules, cubic metres or cubic feet for gas) are very disparate. Nevertheless, any one of these could be used as a basis for recording the other fuels if one had suitable conversion factors. Such factors could be derived from prices, or prices could be used directly to express original units in terms of money values. This is what is done when constructing the energy rows and columns of input/output tables. However, as has already been pointed out prices are a rather unstable attribute of energy sources both through time and between different categories of use for any given energy sources. A more stable and, for many purposes, more useful basis is the energy derivable from one natural unit of each source of energy. This raises the twin problems of which accounting unit to choose and what route to use in order to express units of one fuel in terms of agreed common unit.

138. Before going on to explore these two questions, it should be noted that converting one fuel or source into its energy equivalent in terms of another does not necessarily mean that x units of "energy source B" can in reality be substituted for 1 unit of "energy source A". 35/ For example, one ton of petroleum products may contain the same amount of stored energy as 1.7 tons of coal, but one could not directly replace one ton of motor spirit or diesel oil by 1.7 tons of coal. If we are looking for the quantities of one fuel that would be needed to replace the actually existent (or forecast) quantities of other fuels, we must take account of the uses to which particular fuels are currently put, the equipment that converts such fuel into heat, light or motive power and the scope - which may be limited or non-existent - for using that equipment, as it is or after adaptation, with an alternative fuel.

139. This consideration leads on to two others. The first concerns the different efficiencies with which useful energy can be extracted from the ton of petroleum products or the 1.7 tons of coal. The amount of coal needed to produce a given amount of traction power in transport depends not only on the relative energy contents of coal and oil but also on the relative efficiencies of steam engines on the one hand and of internal combustion engines on the other. The fuel equivalence in this substitution sense may be even more roundabout if petroleum-fuelled engines are replaced by electrically powered trains using coal-fired boilers in the power stations.

140. The second complication arises from the fact that the present level and mix of energy consumption reflects the present supply and mix of energy sources and prices and investment made in the past in fuel-using appliances. With a basically different mix of fuel availability, the level of fuel consumption would almost certainly be very different too. Substitution between energy sources does occur but it is influenced by other factors besides the energy content of each available source.

141. What all this amounts to is that the rate of equivalence between different energy sources depends only partly upon the inherent physical properties of the

energy sources, and partly upon the uses to which they are put. The grade or mix of coal whose calorific content can be regarded as equivalent to 1 cubic metre of natural gas depends on which uses of coal can alternatively be fuelled by gas. The equivalence between electricity and coal or oil depends upon those types of coal or oil that may displace electricity in particular uses. The limited scope for substitution in practice between energy sources does not however render invalid the expression of all energy sources in terms of one or more common accounting units. Such a procedure is perfectly valid and indeed essential in order to be able to study past and present patterns of energy supply and use and to provide a basis for reasoned conjecture about the future.

142. The present Manual does not attempt to cover the whole range of possible accounting units and their numerous cross-coefficients for converting from one to another. This vast field has been thoroughly surveyed and synthesized by Guyol (1977). It is, however, worth drawing attention to a few examples of differences between accounting units - even when called by the same name - and the routes used to express original units of mass in terms of each accounting unit.

2. Tons of coal equivalent (TCE)

143. The SOEC (Luxembourg), the Statistical Office of the United Nations and the United Kingdom have all been using the ton of coal equivalent (TCE) as a common accounting unit, but all three appear to differ in both definition and route. For the SOEC, the TCE used to be defined as yielding 7 Gcal net calorific value; 36/ for the Statistical Office the same energy content used to be defined as the gross calorific value. 37/ For the United Kingdom, the ton of coal equivalent is implicitly defined as having the average gross calorific of all grades of coal in recent years. (The United Kingdom used the long ton for coal until March 1978). 38/ The TCE is also used by several CMEA countries.

144. The route used for converting coal to TCE in SOEC was quite complicated and consisted of adjusting each grade of coal separately, according to its water and ash content, to a standard grade of coal having the specified calorific value. For the United Nations, the route is simple: all bituminous coal (and anthracite) is assumed to have the defined calorific value (net wherever possible). This is equivalent to treating physical tons of coal as already expressed in coal equivalent. The same practice is followed in the United Kingdom. 39/ In all three cases, other solid fuels and other energy sources are converted to tons (or tons) of coal equivalent by using factors that reflect the relative energy values of the defined grade of coal and the energy source in question. In the SOEC, all petroleum products were, up to and including 1977 (see below), treated together without differentiating between the different energy values of each product.

145. Primary electricity (i.e. nuclear, hydro and geothermal electricity) is treated differently in the three cases. In SOEC it is expressed in terms of the fossil fuel - coal equivalent and (since 1978) oil equivalent - that would be needed to generate the same amount of electricity in classical thermal stations on the basis of the average efficiency of all such stations. In the United Kingdom the route is the same but the average efficiency assumed is that of contemporary classical thermal stations. In the United Nations, nuclear, hydro and geothermal electricity is expressed directly in terms of the quantity of coal (of 7 Gcal NCV/ton) that would have the same heat value as the electricity - thus the United Nations does not use the primary fuel input approach.

146. The coal replacement ton used by India is defined as the quantity of coal yielding the same amount of useful energy as 1 unit of each other energy source when employed for a particular purpose (e.g. cooking). 40/

3. Tons of oil equivalent (TOE)

147. The OECD/IEA and the United Kingdom both use the ton of oil equivalent (TOE) as a common accounting unit but, once again, the definition and the route to the unit differ in each case. For OECD/IEA, the TOE is defined as having an NCV of 10 Gcal, (=41.9 GJ) whereas for the United Kingdom, the unit is not formally defined in terms of its calorific value but (as with the United Kingdom TCE) it is defined implicitly in terms of the weighted average GCV of all petroleum products in recent years.

148. In OECD/IEA, the route to thousand TOE is formally by means of first expressing all energy sources in terms of their NCV in teracalories and then dividing the resulting values by 10. In practice, these two steps are combined into one by means of appropriate coefficients. In contrast to the SOEC's detailed adjustment of each grade of coal to a notional standard grade and the aggregated treatment of petroleum products when converting original units to TCE, the OECD/IEA uses the aggregated basis for coal and a product-by-product basis for petroleum products when it converts original units to TOE. Other solid fuels and other energy sources are converted to TOE each by its own coefficient.

149. The United Kingdom does not make any adjustment to the figures of petroleum products and describes its TOE figures as "tons of oil or oil equivalent". Figures for other energy sources are converted to TOE by means of simple coefficients.

150. Both OECD/IEA and the United Kingdom express primary electricity in terms of the primary fuel input that would be needed to generate the electricity. As already stated, the United Kingdom uses the average efficiency of contemporary fossil fuel stations. The OECD/IEA uses the same basis as SOEC, namely the average efficiency of all fossil fuel stations.

151. As from 1 January 1978, SOEC ceased using TCE and adopted the TOE as a presentation unit whilst using the joule as the rigorous accounting unit (see below). From the same date, it converted original units of petroleum products to joules separately for each main type of product. In 1979, SOEC published its overall energy balance in terms of terajoules (see below).

152. The TCE and the TOE have been described first because they are two of the commonest accounting units and they are also used as presentation units to supplement more rigorous and fundamental accounting units.

4. Other accounting units

153. The British thermal unit (BTU) is used in Canada and the United States. It is a very small unit (1 BTU = 0.252 kcal = 1.055 joule) and of the two countries that use the BTU, Canada shows up to 9 or more digits in its published energy balance and the United States uses 10^{12} as a multiplier in its published balance. Tables containing so many digits are inconvenient for quick visual reference by those not accustomed to them.

154. The United Kingdom uses the therm (1 therm = BTU x 10^5 = 25,200 kcal = 105.5 Megajoules) as a rigorous accounting unit and converts in considerable detail each grade of coal (and other solid fuels) and each petroleum product (and other liquid and gaseous fuels), together with electricity, into therms to serve as the basic data for its overall energy balance. (The United Kingdom uses TCE and TOE mainly for presenting simplified balances on a primary fuel input basis, and in such balances great detail on coal and petroleum products is not needed.)

155. The teracalorie (or a sub-multiple of it) has been used by many countries but there are five different definitions of the calorie, ranging in energy value from 4.184 joules to 4.205 joules. The Tcal (equal to 4.186 TJ) was the rigorous accounting unit of SOEC until the Council of Ministers decided in 1971 to drop it in favour of the terajoule as from 1978. The OECD however does not envisage dropping the Tcal, given the very convenient relationship of 10:1 between Tcal and thousand TOE.

156. A few countries (see chapter V) use a large multiple of the joule. (1 terajoule = 10^{12} joules = 0.239 teracalorie). As mentioned above, the members of EEC introduced the joule in 1978. ECE (Geneva) adopted the joule as the accounting unit for the overall energy balance it decided to include as a supplement to its General Energy Statistics for 1978 onwards. The ECE also decided to use the TCE and the TOE as alternative presentation units, to serve as a link with the units retained for the time being by some of its member countries.

157. The joule is the only energy unit recognized in the SI system and was first promulgated as the SI unit of energy in 1946, and then as the SI unit of heat in 1948, by the General Conference on Weights and Measures. Laading (1960) recommended use of the joule in energy balances after considering the merits and limitations of other possible units. Energy analysts who have a physics background have welcomed the joule but there is some resistance to its universal adoption in some countries. The main objection is to its small size and the consequent need for countries of any importance as energy producers or consumers to use a very high power of 10 as a multiplier. Suitable prefixes have however been incorporated in the SI and by using them large numbers of digits can be avoided. These prefixes are best remembered, together with the lower-order prefixes already widely used in electricity statistics, if they are thought of as denoting successively higher powers of 10^3, ...

See Corr.1

<u>RECOMMENDATION:</u>

(20) Given that the joule, and multiples of it by raising it to powers of 10^3, is the only energy unit in the SI, international and national statistical offices should consider adopting the joule (1 joule = 0.239 calorie) as the rigorous accounting unit for energy balances. The TOE (1 TOE = 10^7 kcal NCV) and/or the TCE (1 TCE = 7 x 10^6 kcal NCV) may be used as supplementary presentation units. Whenever they are used, they should be clearly defined in terms of the joule, and the route used for converting original data to TOE or TCE should be clearly described.

V. ENERGY BALANCES

A. General

158. Earlier in this Manual it was stated that any one of a number of energy balance formats (or structures) could be adopted as a basis for international comparisons. No one structure is the right one and all the others defective. Some are nevertheless easier and some are more difficult to follow than others. Some have inconvenient features and some have more concise ways of displaying the same body of information. Some reflect topics of interest to energy analysts at the time the balances were first devised, and some are better suited to meeting simultaneously the needs of historical analysis and future speculation. In this chapter, over thirty balance formats in current use 41/ are reviewed in order to identify those features that should be embodied in any recommendation for an international standard format.

159. The various different purposes for which an energy balance is needed may be summarized by saying that there is a need to know where we have been (the backward glance) and to know - or rather to try to assess - where we are going (the forward look). An energy accounting framework should be suitable for meeting both types of need but there are important differences in the two requirements. Much more data is ordinarily available about the past than is needed when trying to assess the future. Yet the more summary form of analysis that is all that is possible or needed when looking forward five years or more should be conceptually consistent with the fuller analysis that is possible for past years. This compatibility is not a mere matter of statistical purity but is a very practical necessity. To take just one example, a projected future level of primary energy demand must be consistent with the projected levels of consumption of primary and of secondary energy sources. These secondary sources will consist essentially of petroleum products and electricity. The former differ only very slightly (by about 6%) from the mass of crude oil that is needed to produce them (either in the consuming country or in the countries from which it imports petroleum products). The electricity will require about three times as much primary and/or secondary energy sources for its production.

160. There is therefore a need for consistency between supplies of primary energy sources (and equivalents), 42/ deliveries of such sources to electricity generation (and other transformation processes) and to final users, and deliveries of electricity (and other secondary energy sources) to final users. These various flows between the sectors of primary energy supplies, energy transformation and final energy use can be quite complex, and if consistent projections are to be made about the future, it is essential that the nature and relative importance of the many interdependencies have been adequately quantified for past periods. This analysis can be provided by a suitably structured energy balance.

B. Alternative balance formats

161. The form of analysis needed for past years' data and for future years' assessments can differ in more than the level of detail that is necessary or possible. When analysing the past, it is logical to commence with supplies of different energy sources and then to relate each to how it has been used or stocked

or (maybe) lost prematurely 43/ as waste heat. This logical sequence results in what may be called a "top down" energy balance whose generalized form is:

Production
+ Imports
- Exports
+ Stockfall
- Stockrise
= Consumption

162. When assessing the future, on the other hand, it is sometimes convenient to project demand (or consumption) on the basis of its being related in some way to the level of gross domestic product, its structure and distribution, the stock of energy-using equipment and likely developments in the technology of energy use, and to deduce the level of energy supplies that would be needed if the projected level and mix of energy demand is to be met. (So far as any one country is concerned, it is likely to believe that it will be able to obtain - at a price - the required amount of energy by importing it, if that country is not self-sufficient in one more of the energy sources that it thinks it will need.) This equally logical analytical sequence leads to what is sometimes called a "bottom up" energy balance, with the generalized form of:

Consumption
+ Exports
- Stockfall
+ Stockrise
- Production
= Imports

163. Either of these two kinds of balance logic could be used in constructing an energy commodity balance (see chap. II) or an overall energy balance. The present chapter concentrates on the latter kind of balance but of course before constructing such an overall supply and use account, all the necessary data on supplies and uses of each type of primary and secondary energy must be available in original units of measurement. Later on, this chapter considers the problem of aggregating in terms of a common unit of account unlike energy sources. The next few paragraphs leave this particular problem aside.

164. A further distinction that occurs in current practice is between partial balances that only show primary energy sources and complete balances that show primary supplies, transformation of primary to secondary sources of energy, and final uses of both primary and secondary sources. A partial balance of the top down type would look like this:

Source / Flow	Coal	Crude oil	Natural gas	Primary* electricity	Total primary energy
Production Imports (+) Exports (-) Stock change (Rise - Fall +)					
Total inland supply = Apparent consumption or demand					

* Nuclear/hydro/geo/wind.

165. The final line of this table gives apparent inland deliveries (or consumption, if consumers' as well as producers' stock changes are known and can be included in the line "Stock changes"). In practice, it is unlikely that apparent deliveries (or consumption) calculated from supply statistics will exactly match the aggregate of receipts reported by consumers, and an additional line, "Statistical differences", is necessary if it is thought worth giving recorded deliveries (or consumption) in the table. Such recorded inland delivery data would ordinarily relate to deliveries of primary energy sources (and equivalents), to the transformation industries, or directly to final energy uses. It should be noted that apparent demand for primary energy covers use for both energy and non-energy purposes and does not differentiate between them. This further analysis is usually attempted in full balances whenever this is possible.

166. A bottom up balance may also be only partial in that it only displays primary energy sources (as in the case of the above top down partial balance), but the bottom up balance usually requires implicit or explicit assumptions about how final consumption of secondary energy sources is met from the assumed or postulated supply of primary sources (see below). Such a balance would look like this:

Flow \ Source	Coal	Crude oil	Natural gas	Primary electricity*	Total primary energy
Inland deliveries Exports (+)					
Total demand					
Production Stock change (Rise - Fall +) Imports (+)					
Total supply					

* Nuclear/hydro/geo/wind.

167. A complete balance of the top down type would be of the following generalized form:

Flow \ Source	Coal	Crude oil	Natural gas	Petroleum products	Other secondary fuel	Electricity: Primary	Electricity: Secondary	Total
Production Imports Exports Stock change (Rise - Fall +)								
Total supply of primary sources and equivalents								
Oil refining Electricity generation Other transformation industries								
Final use								

168. A complete energy balance may be aggregated or disaggregated. This distinction relates primarily to the number of separate energy sources distinguished in the columns, but a highly disaggregated balance in this sense will almost certainly also be pretty detailed in its treatment of the secondary energy producers' rows. A balance that gives the same amount of detail in the secondary energy producers' rows may, however, be more or less highly aggregated as regards the detail on secondary energy that it shows in separate columns. The many energy balances examined during the preparation of the present Manual showed great variation in the amount of detail set out in their rows and columns.

169. To summarize, the exact order and coverage of the various rows and columns in a balance can and does differ widely in current practice, and the methods used for showing in an overall energy balance the (actual or projected) flows of primary and of secondary energy sources can and do differ too. The essential point to be made at the moment is that the top down and the bottom up approaches are - or should be - mutually consistent. Whatever the order of items and whatever the degree of disaggregation (for the past) or of aggregation (for projections), the

various elements for flows, stocks, energy sources, energy transformations and energy uses should all be capable of being related rigorously to one another in an energy balance so articulated that its essential structure is amenable to collapsing or blowing up without damage to its underlying characteristics.

C. The backward look: "top down" balances

170. The bare-bones of a top down balance have been set out above. There are other basic flows that need to be included even before one considers how many transformation industries to distinguish. For convenience in the rest of this section, rows will be used for flows and columns for energy sources. This is the more common practice but some countries (Austria, 44/ Japan, 45/ Poland and the United States 46/) use the opposite arrangement i.e., rows for energy sources and columns for flows. Following is a more detailed list of the items that should be covered in a complete balance:

- Production
- Imports
- Exports
- Bunkers
- Transformation
  - Input
  - Output
- Energy sector's own use
- Distribution losses
- Non energy use
- Statistical difference
- Final energy use
- Stock changes
  - Producers
  - Importers
  - Transformers
  - Final users

This list is not exhaustive and it does not set out either the only, or most desirable, or the most common order of items. A number of particular items will now be considered in more detail.

1. Stocks

171. Stock changes might be supplemented, or replaced, by stock levels at the beginning of the accounting period (generally the calendar year). EEC records but does not publish stock levels as well as stock changes. Japan shows stock levels and not stock changes, and treats opening stocks as part of supply and closing stocks as part of demand - or more accurately as a category of use of available supplies. 47/ Some balances provide for separate stock changes for producers on the one hand and for consumers on the other (Austria, Italy), but it is not clear where, or whether, importers' and the energy transformation industries' stock changes are covered in these balances. Others are clearer on this point and differentiate between "producers' and importers' stocks" and "transformation industries' and other users' stocks" (ECE and the United Nations Statistical Office). The SOEC balance is even more rigorous in distinguishing between each of

these four categories of stock holder. All the other balances examined only provide for a single figure for a total stock change for each energy source.

172. Some balances use the stock change as a balancing item between total supplies and total uses of each source of energy (Italy, Portugal, Sweden) whilst most of the others reviewed provide a separate item for this. The exact treatment in the cases of Austria and Poland is not completely clear. The Austrian (OSZ) balance appears to use the energy sectors use and loss as the residual item. It is clearly desirable in principle to record measurable stock changes separately but it is recognized that in practice countries often find it difficult to obtain satisfactory data on stock changes with final energy users on a basis suitable for incorporating in published energy balances. This problem is particularly troublesome in the case of non-industrial final users, who are very numerous and therefore costly to include in any regular stocks survey.

173. The most important case in which stock changes need to be adequately assessed is that of the transformation industries because of the need to relate their output to their actual usage of energy inputs: in an energy balance, the entry for inputs to the transformation industries should represent usage and not recorded deliveries to them or receipts by them.

174. The different treatment of stock changes (i.e. treating such changes either wholly on the supply side, or partly on the supply and partly on the demand, or wholly on the demand side of the balance) is one of several examples of treatment differences that result in the same or similar terms such as "total supplies", "gross supply", and "available supply" having different but unpredictable meanings in different balances - unpredictable in the sense that the label used to designate some level of supply gives no indication, on its own, of whether that label denotes a flow that has been measured on the upstream or downstream side of a stock change. It should be noted however that the sub-division of a stock change into two or more components does not necessarily mean that the use-linked components are located in the demand half of the balance. The SOEC balance is the only one - as already noted - that seeks to differentiate between four components of the stock change, yet all four are located in the supply half of the SOEC balance.

175. It may not seem of great importance whether a stock rise is always indicated with a "+" sign (which at first sight seems self-evidently the only logical way to represent a stock increase) or with a "-" sign (which, with equally strong logic can be defended as the only clear way of denoting a stock decrease). This logic is, however, incomplete. A stock change implies a flow; and "+" and "-" signs suggest, respectively, rises or falls in a flow. The sense of the sign used depends on the location of the stock change in an energy balance. If a stock change is located on the supply side of the balance then a stock rise represents a reduction in the supply available for other uses, and in that case a "-" sign would be appropriate (with a "+" sign in the case of a stock fall). If on the other hand a stock change is located on the demand side of a balance, then a stock rise represents an increase in demand, and a "+" sign would be appropriate (with a "-" sign in the case of a stock fall).

176. Among the 20 or so balances reviewed in this section, 8 used the "+" sign and 11 used the "-" sign for a stock rise (and a "-" or a "+" respectively for a stock fall). This seemingly trivial matter can cause mistakes at worst, and avoidable annoyance at best. One of the Italian 48/ balances adds a foot-note to alert the reader to reverse mentally the sign in the supply half of the balance when reading

down the columns of the table but to interpret the sign of the consumers' stock change as it stands. The other Italian balance 49/ uses a minus sign in the supply half but a positive sign in the demand half of the balance to denote a stock rise.

177. The German (Federal Republic) balance and that used by the Brookhaven/Julich team provide separate lines for "Stock withdrawal" and for "Stockpiling". The FEA provisional balance designates its single stock change line (actually a column) as "Stock drawdown", and the New Zealand balance labels the stocks line as "Increase in stocks". These verbal labels do make the interpretation of a negative or positive sign quite clear.

178. Whatever sense of sign is used to denote each direction of a stock change in a line that carries only the neutral label "Stock change", that sense ought to be clearly stated on the table. (This practice is rare in balances published nationally but is followed by the international organizations.) We return to the question of the location of stock changes later.

2. Exports and bunkers

179. Exports and bunkers are generally but not in all cases treated as being essentially similar namely as being charges on the supplies before determining what is available for final use before or after transformation of primary energy into secondary forms of energy. The two Austrian and the two Italian balances, the Japanese official balance and the IEJE balance for France all treat both exports and bunkers as components of demand. 50/ All the balances considered have treated exports and bunkers as two distinct flows, as indeed they are. Bunkers are a precondition for the whole range of international maritime trade and are not so directly related to the oil trade of a country as are its imports or exports of other petroleum products.

180. Almost without exception, bunkers relate to fuel for sea-going ships irrespective of flag of ownership or registration, and do not cover fuel for aircraft engaged on international traffic, or for long distance road goods vehicles similarly engaged. The one exception to this practice is the new United Nations questionnaire that seeks to cover international aircraft bunkers.

181. There is a dual inconsistency here. Firstly, only marine bunkers are covered (and it remains to be seen how successful the United Nations is in collecting data on international aviation bunkers) as a separate flow, with international aviation and road haulage bunkers lost as part of inland deliveries for air and road transport purposes. Secondly, no distinction is made between deliveries of bunker fuel oil (or other products) to nationals of the reporting country on the one hand and to nationals of other countries on the other. According to national accounts conventions, deliveries to nationals of the reporting country should be treated as domestic activity and only deliveries to foreign registered vessels should be treated as being analogous to exports. (Correspondingly, acquisition of bunkers in other countries by vessels owned by nationals of the reporting country should be treated as imports. Such deliveries will be treated as bunkers by the country that provides them.) These facts of current practice, for understandable reasons, are regrettable obstacles to a closer harmonization in the near future, of energy balances with the conventions of input/output tables of inter-industry transactions.

3. Transformation

182. The treatment of the transformation industries in an energy balance poses problems of a different order from those considered so far. It is not simply a matter of examining the best position and the sequence in which transformation industries and their inputs and outputs should occur. The amount of detail (i.e., how many separate industries to distinguish in addition to oil refining and electricity generation) depends on the number of different secondary energy sources that can be or need to be distinguished in the columns of a balance. These other transformation industries or activities could include autogeneration of electricity, the combined production of heat and electricity in industry, heat production in district heating stations, as well as briquetting, gas manufacture or blending, coke ovens and blast furnaces. There are also choices in how losses might be shown, either explicitly or implicitly. These various options can best be considered after other facets of the broader subject have been discussed.

183. Most of the balances that were examined when preparing this Manual cover coke ovens, solid fuel processing (to make smokeless fuel or to consolidate small sized pieces into more manageable briquettes) and gas manufacture (in addition to electricity generation and oil refining). Those that omit one or more of these industries do so because the balance is designed to concentrate on major energy sources or because of the unimportance or non-existence of the industry. Thus the OECD balance provides for gas manufacture but aggregates coal and coal products in its commodity columns and, correspondingly, it does not distinguish any solid fuel processing activity in the transformation block of lines. (The losses in coke making and other solid fuel processing are recorded in the "Solid fuel" column in a subsequent line for "Energy" sector's own use and loss.) The Netherlands balance does not provide for gas manufacture because the activity does not exist. The French (CEREN), Polish and Canadian balances also aggregate all types of solid fuel processing.

184. Blast furnace gas is unambiguously a derived energy source but blast furnaces are an integral part of the iron and steel industry, and frequently so are coke ovens. (Because, however, coke ovens often exist as part of the solid fuel producing industry, coke oven gas production is treated in energy balances as part of the energy sector.) Moreover most blast furnace gas is used within the industry where it is produced, either for feeding back to coke ovens or for heating the blast or for raising steam for electricity generation, and some is bled to waste. This poses the question - already discussed in the context of non-commercial energy sources (see chap. III, sect. B,3) - of whether secondary energy production should be differentiated from energy use when that production occurs within the final use sector.

185. The most detailed analysis of energy production and of use by each final use sector is given in the "make" and "absorption" matrices that accompany the official Austrian balance. 51/ There, blast furnaces as such are not distinguished because the matrix uses the Austrian standard classification of industries. The production of blast furnace gas (and also of coke and coke-oven gas) is recorded in the row for the iron and steel industry. No other energy balance examined has such detailed supporting analyses of final energy users but blast furnaces are treated as part of the energy sector in the balances of Federal Republic Germany, Italy, Norway, Portugal and Sweden and in the international balances of EEC, SOEC, ECE (Geneva) and Brookhaven/Julich and in the United Nations Statistical Office (New York) questionnaire. Other countries take the view that because blast furnace gas

production and use is (with the rare exception of sales to adjacent industries) wholly internal to the iron and steel industry, there is no need, or value, in striving to show the flows separately in an energy balance.

186. The same sort of problem also arises in the case of electricity generation within industry from energy sources that have been purchased from outside. This problem is made more complex by the occurrence of the joint production of electricity and heat (CHP). (Indeed, the same is true in the case of at least some electricity production from steam produced with the heat from blast furnace gas.) This heat is used almost wholly within the industry in which it is produced and would necessitate the purchase of additional quantities of fuel if that heat was produced from a heat-only plant. The balances for Canada, France, (CEREN), Federal Republic of Germany, Japan, Netherlands and Sweden, together with some of the international bodies' balances distinguish autogeneration of electricity on a separate line.

187. Most balances give details of inputs and outputs for the transformation industries in the body of the balance itself. Three countries (Austria, Italy and Sweden), however, show only single rows for transformation input and output, respectively, in the main balance but supplement this with more detailed tables on inputs and outputs of each transformation industry. The Italian official balance goes even further and allocates the process loss in each transformation industry to each input fuel. (This is done by splitting for each plant the total energy input in proportion to secondary energy output and losses, and then aggregating, across plants, first the energy and then the loss components of input.)

4. Combined generation of heat and electricity (CHP)

188. This leads on to the problem of whether, if the production of electricity by industry (with or without the joint production of heat) is shown separately in a balance, the electricity and the heat should cover total production and use, or only those amounts sold and used outside the industry where they are produced. These problems have already been discussed in chapter III.

189. A related but different activity is the production of medium or low temperature heat for urban district heating in heat-only stations. Those balances that provide a line for this (Austria, Federal Republic of Germany, Sweden and the international balances of ECE and Brookhaven/Julich) also provide a column for the output of heat, and this column is used for recording in addition heat produced jointly with electricity in public supply and industrial autogeneration power plants. The Netherlands balance has no line for heat production but it does have a column for heat. In this column there is recorded a large figure for primary production. This is the heat content of the steam produced in nuclear power stations plus that produced by burning municipal and industrial waste. There are also entries for heat produced in oil refineries and public supply power stations. There is a corresponding entry for the heat inputs to electricity generation but most of this total supply of heat is shown as consumed by industry as the final user.

190. A more difficult question is that of where to record the fuel input to the joint production of heat and electricity. The Swedish balance provides separate lines for electricity only, heat only and for CHP stations, and the ECE balance 52/ (for individual fuels) does likewise. This is a neat solution since it avoids the need to consider splitting the fuel input between the joint products heat on the

one hand and electricity on the other. In the cases of those balances that provide for heat stations and electricity stations (but not for CHP stations) - namely, Austria, Federal Republic of Germany and Brookhaven/Julich - it seems that the heat that is in fact produced by industrial CHP plant is recorded in the row for district heat even though most of this industrially-produced heat is used in the industry where it is produced, and the fuel for such heat is recorded in the row for the industry that produces the electricity. It follows - if this is in fact the convention followed in those balances - that the inputs attributed to heat production are too low and the inputs attributed to autogeneration of electricity are arguably too high in relation to that electricity.

191. The word "arguably" is used deliberately because the question of whether inputs to joint products should be allocated between those products stands for the moment unanswered. On the one hand, there are those who maintain that such an allocation can only be artificial and must be based on some more or less arbitrary convention and should, therefore, not be attempted. On the other hand, there are those who maintain that energy analysis (see chap. I, sect. C) cannot be carried out unless one can trace all the upstream energy inputs to a commodity or to a process, and that if one of the inputs is electricity produced through CHP, then one has no choice but to allocate on some basis the energy inputs to that generation between the two energy outputs. This problem is considered in more detail in annex I. 53/ Whether or not a separate row is provided in a balance for CHP, and irrespective of whether autogeneration of electricity is recorded as part of transformation or as part of final use, there is no absolute necessity to split inputs to CHP between different rows (i.e. between different outputs). The most neutral way of presenting the information is to record the inputs and the two outputs in the single row for the activity.

192. Some balances that make no specific provision in the form of a line for heat production, either in heat-only stations or as one output from CHP plants, do nevertheless provide for recovered waste heat to be recorded, together with heat produced by burning urban or industrial waste materials, either in a special column (Italy, Netherlands and Poland) or by including electricity produced from heat recovered from waste products (Portugal, EEC and SOEC).

5. Non-energy use

193. This flow is less simple than it seems. It covers two relatively straightforward elements, namely the use for non-energy purposes of products that are of their nature energy sources (e.g. coal, natural gas, liquefied petroleum gas and naphtha) and the use of products that are rarely or never - so far - regarded as energy sources (e.g. lubricants, waxes, white spirits). The Italian balances distinguish clearly between these two flows. All the other balances distinguish the use but not the two product groups.

194. The complications arise because (as mentioned earlier) part of the coke used in blast furnaces can be considered as a feedstock rather than as a fuel. The Netherlands balance provides a column for imports of carbon black feedstock oil, all of which goes to non-energy use (mainly as a filler in rubber manufacture). One could argue that imports and exports of electrodes should also be included because these are an alternative to importing and exporting petroleum coke (which is largely used in their manufacture). Once again, there is a conceptual relationship between the lines for activities or uses and the columns for

commodities, and the exact commodity coverage of an energy balance should always be made clear.

6. Final users

195. The amount of detail shown in this part of current balances varies greatly. All make some split between industry, transport and other final users. The number of industries distinguished separately is 30 in Austria, about 20 in the Federal Republic of Germany, about 15 in France (CEREN) and Japan (IEE), about 10 in Argentina, Italy (Ministry of Industry and Commerce), Netherlands and Brookhaven/Julich, and only about 5 or fewer in the other balances examined. Some countries (e.g. the United Kingdom) give only a summary of industrial energy use in the energy balance itself and give considerably greater detail in satellite tables. The number of modes of transport varies from 1 to 5. The treatment of the remaining sectors - in particular whether domestic or residential users are distinguished - also differs between cases. The Polish balance treats the energy industries' own use as a component of final use.

196. We take up later the question of the desirable degree of detail as between users and the purposes for which energy is used. The Brookhaven/Julich balance has reduced the number of user categories in order to have space to split the domestic and (separately) commercial lines between space heat/water, heat/other, and to split road transport between bus, truck and automobile. Other splits are possible and a number of them are used in one of the bottom up balances examined later in this chapter.

7. Original units and common accounting units

197. Many of the balances examined are published in pairs with the same structure, with one member of the pair showing original units and the other member showing the same data expressed in the chosen common accounting unit (see below). This practice is followed by Canada, Federal Republic of Germany, Italy, Norway, Netherlands, Portugal and Sweden. In the case of Austria, the balance in the common accounting unit gives no detail at all on the transformation industries or on the make-up of the final use sector, but the accompanying "make" and "absorption" matrices, which only give data in original units are, as already mentioned, very detailed. The United Kingdom published for each of nine industry groups separate data in original units and in common units for the deliveries of each main type of fuel.

198. The French (CEREN) balance shows in a single balance the original units in detail for each broad type of energy source (solids, liquids, gases and electricity) and follows with a group of columns giving line-totals for each source-type for each element of the balance expressed in the common accounting unit. The unpublished Polish balance uses a pair of columns for each energy source, with original units in the first column and common accounting units in the other.

199. Up until 1978 the SOEC balances separate the component energy-source balances from the all-sources-total balance in order to be able to tabulate time series more easily. The original data that lie behind the overall balance can thus be found spread between the time series tables for each energy source. In 1979 SOEC adopted the matrix structure for its balances and published the tables in pairs, one member of which showed original units and the other common units.

200. As regards the common accounting unit, the terajoule (or some multiple of it) was already in 1977 used by five countries (New Zealand, Norway, Portugal, Sweden and the United Kingdom), and all the other members of the European Economic Community (Belgium, Denmark, France, Federal Republic of Germany, Ireland, Italy, Luxembourg and the Netherlands) adopted TJ in 1978. Austria intends to do likewise and Poland and Hungary propose to adopt the TJ in 1980. The TJ is also used in the Nordic Yearbook of Statistics and in the new energy balance of the Economic Commission for Europe (ECE), in the papers of the WEC Conservation Commission and by Nebbia. The new SOEC balance introduced in 1979 also uses the TJ.

201. The teracalorie (or some multiple of it) is at present used by at least seven countries - Argentina, Austria (OSZ), Hungary, Japan, Mexico and Poland and by the provisional FEA balance in the United States). The ton of oil equivalent (TOE) is currently used by OECD, Brazil, Finland, France (CEREN), EEC (Brussels) and SOEC (Luxembourg) and at least two major oil companies. The ton of coal equivalent (TCE) is at present used by Austria (OIW), France (IEJE), and the United Nations (series J). As was pointed out in chapter IV, section H, the use of the same name, such as TOE or TCE, to designate an accounting unit does not mean the route to that unit is the same even when the definition of the unit in terms of its energy content is identical.

202. The standard barrel of oil per day is used in some oil companies' energy balances. The British thermal unit (BTU) is used in Canada and the United States in their published balances, and the therm is still used in the United Kingdom (in addition to the TJ). The United Kingdom also uses the TOE and TCE as presentation units.

8. Calorific values of fuels

203. All countries except Canada, Japan, New Zealand, the United Kingdom and the United States use NCV.

9. Aggregation of energy sources

204. When considering alternative treatments of the row headings for the transformation industries, it was pointed out that the options had to be looked at in conjunction with the treatment of those industries' inputs and outputs in the energy commodity columns of a balance. This is a particular case of the problem of aggregating across energy sources, which we shall now examine in a generalized form.

205. For simplicity the remainder of this section will take the case of a hypothetical country with the pattern of separate energy flows shown in the following table. Each column represents a simplified energy commodity balance in which each figure is assumed initially to show quantities measured in the physical accounting unit most commonly used for each energy source (tons for solid and liquid fuels and kWh for electricity). There can be no total column at this stage.

Energy commodity balances

Flow \ Source	Coal (C)	Crude oil (O)	Refined products (R)	Electricity (E)
Production	100	-	95	30
Imports	10	100	-	-
Exports	-	-	1	-
Total supply	110	100	94	30
Transformation input		100	90	-
Final use	110	-	4	30
Total demand	110	100	94	30

Stock changes, the energy industries' own use, bunkers, distribution losses and non-energy uses are deliberately ignored since they do not affect the argument. With these simplifications, the 20 top down balances considered in this section can be reduced to six basic forms. To simplify things further, the full row and column headings will not be repeated but will be denoted by the letters shown in the above table. (Later, we shall introduce alternative treatments of electricity, reflecting the range of existing practices.)

206. Let us now assume that the figures in the above table have already been converted into a single accounting unit (e.g. the terajoule). The table would then show that the country produced 100 TJ, imported 10 TJ and consumed 110 TJ of coal without using any of the coal for conversion into coke, other solid fuel products, gas or electricity; it imported 100 TJ of crude oil and from that derived 95 TJ of refined products of which 1 TJ-worth was exported and 4 TJ went into final consumption. The other 90 TJ were used as an input to electricity generation, with an output of 30 TJ all of which was consumed by final energy users.

207. Let us now add a total column in order to make the four separate balances into an overall energy balance:

<u>Overall energy balance: type I</u>
(In terajoules)

Flow \ Source	C	O	R	E	Total
Production	100	-	95	30	225
Imports	10	100	-	-	110
Exports	-	-	1	-	1
Total supply	110	100	94	30	334
Transformation input	-	100	90	-	190
Final use	110	-	4	30	114
Total demand	110	100	94	30	334

The arithmetic is straightforward and this is the basic <u>form</u> of the Italian (Ministry of Industry and Commerce), Norwegian, Polish and Portuguese balances (although the treatment of electricity differs in each of these cases).

208. A weakness of this structure is that the total of the first row, and consequently total supply, double-counts the primary energy sources used for transformation: in the production row the 95 TJ of refined petroleum products contains the 30 TJ of electricity, and in the total supply row, the 100 TJ of crude oil contains the 95 TJ of refined products (of which 1 TJ was exported) which itself contains the 30 TJ of electricity (so that one could argue that the electrical energy is even counted three times). This double-count is eliminated by the transformation input row, but the fact remains that there is double-counting in the figure for supply.

209. One way around this problem is to count in the total column of the production row, only the primary energy source(s) in that row. If this is done, the entry in the total column in the transformation row can consist only of the losses in transformation: these together with the total quantities of secondary (and primary) energy supplied to final energy users make up the total use of the available supply of energy. This is the basic form of the Italian (ENI) balance:

Overall energy balance: type II
(In terajoules)

Flow \ Source	C	O	R	E	Total
Production	100	-	(95)	(30)	100
Imports	10	100	-	-	110
Exports	-	-	1	-	1
Total supply	110	100	94	30	209
Transformation input	-	(100)	(90)	-	65
Final use	110	-	4	30	144
Total demand	110	100	94	30	209

Although this device eliminates the double-counting, it makes the balance less easy to follow, and the relationship between row cell entries and row totals can become elusive when there are many columns. The true transformation inputs may be tabulated (as shown in brackets) but only the transformation loss (i.e. the difference between the 190 TJ input and 125 TJ transformation output) is shown in the total cell in the transformation row.

210. Some countries (Austria (OSZ), Netherlands up to and including 1976 but now changed, France (CEREN) and New Zealand) distinguish between a row for primary energy sources and a row for production of secondary energy sources in the supply section of the balance, and thus show clearly the inputs to and the outputs from transformation but at the same time double-counting is re-introduced into the supply total rows. In the following table, the secondary production row has been called "Transformation output" (TO).

Overall energy balance: type III
(In terajoules)

Flow \ Source	C	O	R	E	Total
Primary Production	100	-	-	-	100
Transformation output	-	-	95	30	125
Imports	10	100	-	-	110
Exports	-	-	1	-	1
Total supply	110	100	94	30	334
Transformation input	-	100	90	-	190
Final use	110	-	4	30	144
Total demand	110	100	94	30	334

The four country balances just mentioned, in fact follow the sequence: primary production ... imports ... production of secondary sources. The CEREN balance interposes a sub-total "total primary supplies" before deducting exports. The New Zealand balance distinguishes between "gross supply", including the double-count, and "net supply" which is a row interposed after the row for the input to transformation. The Austrian (OSZ) balance treats exports as a component of demand rather than as a diminution of supply. (The same convention for exports is followed in the Japanese (SOGO) balance, but the basic structure of both the Japanese balances is different: see below.) This has the effect of altering the actual figures for total supply and total demand - one of many examples of how the same concept can have significantly different meanings.

211. A more rigorous framework is used in seven other balances, 54/ and is seen most clearly in the German (Federal Republic) and Brookhaven/Julich balances and in the latest SOEC balance. All of these balances treat quite separately production of primary energy sources on the one hand and the production of secondary sources on the other. The balance is structured in three distinct parts (primary supplies, transformation and final use) rather than the usual two (supplies and uses):

<u>Overall energy balance: type IV</u>
(In terajoules)

Flow \ Source	C	O	R	E	T
Production	100	-	-	-	100
Imports	10	100	-	-	110
Exports	-	-	1	-	-
Total supply	110	100	-1	-	209
Transformation input	-	100	90	-	190
Transformation ouput	-	-	95	30	125
Difference	-	-100	+5	+30	+65
Final use	110	-	4	30	144

The "Difference" row has been added to show the net output of the transformation sector. This row does not appear explicitly in the published balances and may seem anomalous in that it appears to show a process gain in the transformation of crude oil into refined products. At the same time, this structure of balance has retrieved the overall transformation sector loss (65 TJ) but without the inconvenient feature of the balance shown in type II.

212. The apparent anomaly of the process gain disappears when the transformation input and output rows are disaggregated into their component energy industries:

Overall energy balance: type IV
(In terajoules)

Flow \ Source	C	O	R	E	T
Production	100	-	-	-	100
Imports	10	100	-	-	110
Exports	-	-	1	-	1
Total supply	110	100	-1	-	209
TI (Refineries	-	100	-	-	100
(Power stations	-	-	90	-	90
TO (Refineries	-	-	95	-	95
(Power stations	-	-	-	30	30
Final use	110	-	4	30	144

The Austrian (OIW) overall balance gives no split of the inputs to separate transformation industries, and neither this Austrian balance nor the provisional FEA balance shows whether the output of any one derived source of energy comes from one or from more than one transformation industry. This does not matter if only as many types of energy output are distinguished as there are transformation industries, with each such industry having only one type of output. If, however, one output is produced from two or more energy sources or industries, then it is desirable to sub-divide the industries so as to show clearly the relationship between the inputs to each form of derived energy.

213. Take the case of a product that may be derived either from coal or from crude petroleum (e.g. a gas with particular characteristics). Then it is desirable to introduce a new row (as well as a new column).

Overall energy balance: type IV, slightly expanded
(In terajoules)

Flow \ Source	C	O	R	W*	E	T
Production	100	-	-	-	-	100
Imports	10	100	-	-	-	110
Exports	-	-	1	-	-	1
Total supply	110	100	-1	-	-	209
TI (Refineries	-	100	-	-	-	100
(Power stations	-	-	90	-	-	90
(Gas plants	10	-	4	-	-	14
TO (Refineries	-	-	95	-	-	95
(Power stations	-	-	-	-	30	30
(Gas plants	-	-	-	12	-	12
Final use	100	-	-	12	30	142

* Works gas

The German and Brookhaven/Julich balances distinguish - as already mentioned - between a dozen separate transformation activities. The Swedish, United States (FEA) and SOEC balances distinguish somewhat fewer. The SOEC balance (until 1978) looked rather different from the above form because, as mentioned previously, it tabulated the individual energy-source balances as a group separately from the total all-sources balance, and listed the data for each energy source under each of the above row headings, as an aid to publication of time series, thus:

Production
  Coal
  Crude petroleum
  .
  .
  .

Imports
  Coal
  Crude petroleum
  .
  .
  .

214. The Canadian balance uses quite a different solution to the double-count problem. It constructs two similar but distinct balances, one for primary energy sources and the other for secondary sources, and then aggregates the net supplies resulting from each, thus:

Overall energy balance: type V
(In terajoules)

Flow \ Source	C	O	R	E	T
Primary Sources					
Production	100	-	-	-	100
Imports	10	100	-	-	10
Exports	-	-	-	-	-
Transformation input	-	100	-	-	100
S_1	110	-	-	-	110
Derived sources					
Production	-	-	95	30	125
Input	-	-	-	-	-
Energy	-	-	1	-	1
Transformation input	-	-	90	-	90
S_2	-	-	4	30	34
Total: S_{1+2}	110	-	4	30	144
Final use	110	-	4	30	144

This does get around the double-count problem but it does also involve a lot of blank cells, particularly in the first part of the balance. A similar approach is used in the French official balances 55/ which go even further and show a mini balance for each energy source separately. These French balances are not easy to use because all the figures for individual energy sources are only given in original units, with only the all-energy total expressed in a single unit of account (the TOE), and the relationship between the component figures and the respective totals (where totals occur) for rows is sometimes rather unclear.

215. Of the balances reviewed in this section so far, the type used by Federal Republic of Germany, Brookhaven/Julich, and that adopted in 1979 by SOEC are the most clear and the most informative, largely because of the amount of detail it can show on inputs to and outputs from each transformation industry. Even so, some double-counting remains (as the Notes to the German balance point out) because the

balance includes separate total rows for, respectively, inputs to and outputs from transformation. The input total includes crude going to refineries and fuel oil going to power stations. The output total includes petroleum products and electricity. This part of the balance does, however, take up a lot of space that could be better used, for example by adopting a more legible size of type-face for the whole table or by expanding the final use section so as to give some information on the main purposes (space, heat, process heat, motive power, light...) for which energy is used within each final use class. 56/

216. Very few of the cells in the transformation section of the balance have both input and output entries. Consequently, little or no information is lost by adding in the matrix sense (i.e., adding cell-by-cell, or superimposing) the input and output sub-matrices of the balance. Such a procedure has the advantage not only of making valuable space available for new information (e.g. a more detailed analysis of final use), but also of making explicit the heat losses occurring in each transformation process. Inputs must now be shown with a minus sign and outputs with a plus sign in the same row, and in this way the heat loss appears with a minus sign in the 'Total' column:

Overall energy balance: type VI
(In terajoules)

Flow \ Source	C	O	R	G	E	T
Production	100	-	-	-	-	100
Imports	10	100	-	-	-	110
Exports	-	-	-1	-	-	-1
Available supply	110	100	-1	-	-	209
Gas plants	-10	-	-4	+12	-	-2
Refineries	-	-100	+95	-	-	-5
Power stations	-	-	-90	-	+30	-60
Final use	100	-	-	12	30	142

This structure of balance is used by Finland, Japan, the United Kingdom, OECD and in the new energy balance of ECE (Geneva). Exports have been shown with a negative sign, but the row heading is normally treated as a clear indication of the need to subtract the row figures when adding any column. 57/

217. It is economical in the use of space, yet clear once one is accustomed to interpreting the sense of the signs in the transformation section. Reading across, for example, the row for refineries, we see that the inputs of 100 TJ of crude oil gave an output of 95 TJ of petroleum products with a refinery loss of 5 TJ. Reading up and down the refinery column, we see that the output of 95 TJ was used as follows: 90 TJ went into power stations for electricity generation, 4 TJ went to gas plants as one of the inputs for gas production (the other input was 10 TJ of

coal) and 1 TJ was exported. No information need be lost, since any row or column can always be divided into two (or more) if, for any country, any transformation cell with the existing number of rows and columns would contain both input and output data. At the same time, a more detailed balance can readily be collapsed to a higher level of aggregation. Not least, all double-counting is eliminated.

10. Nuclear energy

218. Nuclear, hydromechanical and geothermal (and other renewable) sources of energy introduce a problem already discussed from another point of view in chapter IV, sections C and D. They are converted into electricity but they do not fit into the accounting frameworks we have been considering except by making some new type of measurement or by adopting some convention so as to be able to be expressed in the chosen unit of account. This problem has two facets in the case of those countries that prepare balances in both original units and in a common accounting unit. In this present section, we shall only consider nuclear energy.

219. Annex II gives a summary account of the nature of nuclear fission and how it is harnessed in order to generate electricity. The two essential characteristics that are relevant to the present discussion are, firstly, that the amount of energy obtainable from a given amount of nuclear fuel depends upon the type of reactor in which fission occurs; and secondly, that the amount of energy obtained during one year from the nuclear fuel in the core of any type of reactor is only a very small fraction of the total amount of energy that is recoverable, with current technology, over the whole useful life of a reactor. It follows that if stocks and flows of nuclear fuel are to be fitted into an energy balance as well as the electricity produced from the fission heat, there is a need to relate the energy value of fuel stocks to the existing population of reactors and to current nuclear fuel preparation and recycling technology. Strictly speaking, this would mean that when technology changed, one should revalue the energy content of fuel in the cores of existing reactors. As has been suggested, 58/ the problem is rather like being able to obtain only part of the heat that is stored up in power station coal and having a part-burnt storable residue whose recoverable energy depends on current and future coal-combustion technology.

220. This daunting problem is considered further in annex III. In the energy balances examined when preparing this Manual, none of the countries having nuclear power stations attempts to quantify (in its balances) nuclear fuel stock changes. Four seek to quantify the consumption of nuclear fuel, either in mass terms (Italy and Netherlands) or in an energy unit such as the TCE (Federal Republic of Germany) or TOE (Sweden). The basis of the Italian estimates is not completely clear. The Netherlands shows the heat output from reactor cores in terms of the quantity of steam used as input to nuclear generation of electricity. The German and Swedish figures are derived backwards by assuming nuclear electricity generation efficiencies somewhat below that observed in classical thermal power stations (Sweden) or equal to that obtainable in classical stations (Federal Republic of Germany). The German method is also used in the Brookhaven/Julich balance. None of the other countries or the international bodies show nuclear fuel as an energy source but show only nuclear electricity (though it is called "nuclear energy" in some balances).

221. In the balances in a common acounting unit, the almost universal practice is to represent nuclear energy by the fossil fuel equivalent of electricity generated

in nuclear power stations. Canada, New Zealand and the United Nations (series J) alone show nuclear electricity in terms of its heat value (and not of its fossil fuel equivalent). The percentage generating efficiencies used vary considerably from balance to balance, and there is a consequent problem of comparability between countries. 59/

222. All countries with nuclear electricity except Germany, and the international balances of EEC, SOEC (until 1978) and OECD, show the production of nuclear electricity as being a wholly domestic activity with no dependence on imports. The German (Federal Republic of) balance records nuclear electricity as imported. In 1979, SOEC adopted the same principle but shows a national import of heat rather than of coal equivalent. (In the case of France, which has some indigenous uranium, the SOEC balance shows primary heat as both imported and as domestically produced.)

223. Annex III considers in greater detail the conceptual basis for a complete balance for nuclear energy. A more realistic basis for developing current practice towards full accounting would be to adopt the following principles in national energy balances:

(a) In the main energy balance, "Nuclear electricity generation" should have its own row. A new column should be added for "Nuclear fuel". The entry in the common cell should be the recorded or estimated heat release (or fuel burn-up) in the reactor (with a negative sign). This same figure should be carried up in the column and repeated (with a positive sign) either in the "Production" or the "Import" row, according to whether the country concerned was a producer or an importer of uranium ore. For simplicity (in the main balance), no attempt should be made to distinguish whether imported ore was enriched or fabricated in the country that used it or to show export of any nuclear material. A new row would in principle need to be introduced for fuel processing and in particular isotopic separation plants, so that the balance could show the electricity flow to this energy-intensive industry. The row should ideally be located in the transformation section or the final use section of the balance, but if confidentiality reasons would make this unacceptable, then at least the electricity used by the nuclear processing industry should be included in the "Other industry" row in the final use sector.

(b) In a satellite table, rows and columns should be provided to accommodate the flows to and from thermal reactors (as illustrated in diagram I, annex III). Such a table should show the available data at least in original units (tons). If possible, a second table with the same structure should show the same flow in terajoules. For the conversion into terajoules, the factor should reflect current nuclear technology (namely LWR with three recyclings of irradiated fuel or HWR with no recycling. These two technologies have approximately the same conversion factor.)

11. Hydromechanical and geothermal energy

224. These two sources of energy do not have the stock problems of nuclear energy: conveniently (for the present purpose) the stocks of water and geothermal heat are regarded as reserves, or resources, and are, therefore, outside the scope of the present Manual. However, there remains the problem of how to quantify the primary input to electricity generated from hydro or geothermal energy.

225. There are, as pointed out in chapter IV, three approaches to this. Those countries for whom hydropower is important because it is plentiful, and therefore cheap, have developed patterns of energy consumption that are heavily dependent on (cheap) electricity. For such countries, it would be very artificial to express hydroelectricity in terms of the energy content of the fossil fuel that would be needed to produce the same amount of electricity because (they very reasonably argue) they would not use so much electricity if they could not produce it cheaply from abundant hydromechanical power. The Swedes, the Austrians and the Italians (MIC) use the average efficiency of hydroelectric stations (80-85%) in order to express hydroelectricity in terms of its notional primary energy input.

226. The Canadian, French (IEJE), New Zealand, Norwegian and United States (FEA) balance treat hydroelectricity as itself representing primary energy: this is the second approach, based on the proposition that, with the exception of small and relatively unimportant cases of the direct harnesssing of hydromechanical power for machine drives, hydropower must be converted into electricity before being suitable for widespread use.

227. The third approach is to do the same as in the case of nuclear energy and use the partial substitution energy model, or opportunity cost basis. This is the approach used in the ENI balance for Italy and in the balances for Federal Republic of Germany, Portugal, SOEC and OECD, but the actual percentage efficiencies vary considerably between balances.

228. Geothermal electricity is expressed as heat energy in the New Zealand balance, in fossil fuel equivalent in the Italian (ENI) balance but on a notional physical energy basis (using an efficiency of about 10%) in the Italian (MIC) and Nebbia balances.

229. Because of the radically different results obtained by the opportunity cost basis on the one hand (using an efficiency of about 35%), and by the notional primary energy input basis on the other (using an efficiency of about 85% for hydro and about 10% for geothermal), the new ECE (Geneva) and United Nations Statistical Office balances provide for data on both bases to be incorporated in the same table. The same solution is adopted for some analyses in Darmstadter (1971).

230. It will however be recalled that recommendations have already been made for recording hydroelectricity as electricity but with the fossil-fuel input equivalent as an additional statistic (para. 105) and for recording geothermal heat as such (para. 114). The following illustrative examples show how these various bases for treating hydro and geothermal (and nuclear) electricity could be entered in an overall energy balance.

12. Treatment of primary electricity

231. Columns are added for nuclear, hydro and geothermal electricity and as many rows are introduced in the transformation section of the balance. The three balances which follow also illustrate the effects of changing the generation efficiencies used for evaluating the primary energy inputs, from 33% to 100% for nuclear (the latter is equivalent to treating nuclear electricity as itself primary energy), from 33% through 75% 60/ to 100% for hydro (and again the 100% is equivalent to treating hydroelectricity as primary energy), and from 33% through

10% to 100% for geothermal electricity (with the same interpretation as before for the 100%). The cases are summarized below:

Assumed generation efficiencies

(Percentages)

Case	Nuclear	Hydro	Geothermal
A	33	33	33
B	33	75	10
C	100	100	100

Effects of alternative assumptions about efficiencies of generation for primary electricity: three balances

(In terajoules)

CASE A

Flow \ Source	Coal	Oil	Refined products	Nuclear	Hydro	Geo	Electricity	Total
Production	100	-	-	10	10	10	-	130
Imports	10	100	-	-	-	-	-	110
Exports	-	-	1	-	-	-	-	1
Primary supply	110	100	-1	10	10	10	-	239
Generation:								
Nuclear	-	-	-	-10	-	-	+3	-7
Hydro	-	-	-	-	-10	-	+3	-7
Geothermal	-	-	-	-	-	-10	+3	-7
Classical	-	-	-90	-	-	-	+30	-60
Total	-	-	-90	-10	-10	-10	+39	-81
Refineries	-	-100	+95	-	-	-	-	-5
Final use	110	-	4	-	-	-	39	153

CASE B

Flow \ Source	Coal	Oil	Refined products	Nuclear	Hydro	Geo	Electricity	Total
Production	100	-	-	10	4	30	-	144
Imports	10	100	-	-	-	-	-	110
Exports	-	-	1	-	-	-	-	1
Primary supply	110	100	-1	10	4	30	-	253
Generation:								
Nuclear	-	-	-	-10	-	-	+3	-7
Hydro	-	-	-	-	-4	-	+3	-1
Geothermal	-	-	-	-	-	-30	+3	-27
Classical	-	-	-90	-	-	-	+30	-60
Total	-	-	-90	-10	-4	-30	+39	-95
Refineries	-	-100	+95	-	-	-	-	-5
Final use	110	-	+4	-	-	-	+39	153

CASE C

Source / Flow	Coal	Oil	Refined products	Nuclear	Hydro	Geo	Electricity	Total
Production	100	-	-	3	3	3	-	109
Imports	10	100	-	-	-	-	-	110
Exports	-	-	1	-	-	-	-	1
Primary supply	110	100	-1	3	3	3	-	218
Generation:								
Nuclear	-	-	-	-3	-	-	+3	-
Hydro	-	-	-	-	-3	-	+3	-
Geothermal	-	-	-	-	-	-3	+3	-
Classical	-	-	-90	-	-	-	+30	-60
Total	-	-	-90	-3	-3	-3	+39	-60
Refineries	-	-100	+95	-	-	-	-	-5
Final use	110	-	4	-	-	-	39	153

232. It will be seen that the changes in the assumed generation efficiencies alter the total of primary energy required and the conversion losses but not the level of final energy use:

Relation between primary energy and final use

(In terajoules)

Case	Primary energy requirement	Transformation loss	Final energy use
A	239	86	153
B	253	100	153
C	218	65	153

This table provides another example of how the same label can denote very different quantities, and of the great importance of defining clearly the route by which original units of measurement have been converted to the common accounting unit and the assumptions used in constructing entries in an energy balance.

233. In all three cases, the primary electricity has been transformed in the transformation section of the balance from the column of origin to the main electricity column. This is done partly because the nuclear, hydro and geo columns represent, in principle, energy inputs to the activity of generating electricity, and also because it is rarely (if ever) possible to know whether electricity, consumed by any given class of user, is originally from power stations of any particular type; it would not be possible in practice to allocate the 39 TJ of electricity in the "Final use" row between the nuclear, hydro and geo columns.

234. Before leaving this survey of the variety of practices in treating electricity in energy balances, it is of interest to note that the French and till now, EEC and SOEC balances treat all electricity, including that produced in fossil fuel stations, only in terms of its actual or imputed fossil fuel input.

235. Another less common treatment is to express imports and exports of electricity in terms of fossil fuel equivalent (France (CEREN), Federal Republic of Germany, Portugal and Brookhaven/Julich) and SOEC until the basis was changed in 1979. Italy (ENI) expresses imports but not exports in such terms. This treatment causes a minor problem in those balances which do not use fossil fuel equivalent of electricity throughout the balance (i.e. Federal Republic of Germany and Brookhaven/Julich) because the exhaust heat imputed to net imports has to be accounted for subsequently in the balance. This could be done by channelling imported electricity through the domestic generation industry (as in the ENI balance), thus including the imputed waste heat in the overall heat loss on domestic generation, if the foreign trade in electricity is recorded in one of the primary electricity columns. If, however, trade in electricity is recorded in the "Secondary electricity" column (which shows the output from generation) this device is not possible. The German and Brookhaven/Julich balances solve the problem by including the imputed waste heat as a valuation difference in the losses row.

236. Renewable energy sources such as solar, biogas, wind, wave and tidal energy can be incorporated by adding one or more further columns. Energy converted into electricity may be channelled through the transformation sector in the same way as in the above examples. Energy converted directly into heat may be recorded directly as TJ of heat in the production row of its column and then be accounted for down its column as going to transformation (e.g. electricity) or directly to one or more final users.

237. All except one of the balances examined that are used for regular analysis of past periods are of the top down type. We shall now consider the alternative approach, its usefulness and the relationship between it and top down balances.

D. The forward look: "bottom up" balances

238. The balance published by the United States (Bureau of Mines) is a bottom up balance showing final use of energy from each main source by each main final use sector and by power stations, but it is incomplete in that it does not show the origin (in production, foreign trade or changes in stocks) of energy sources. This balance information is however complemented by tables giving greater detail on the components of each main energy source and showing production and trade origins, destinations and uses. The general form of the balance is as follows. The quantities shown in the following table are in exajoules (EJ), (TJ x 10^6):

Source / Flow	Solid fuels	Natural gas	Petro-leum products	Hydro power	Nuclear power	Total	Elec-tricity	Total
Industry	4	9	6	-	-	19	3	22
Transport	-	-	18	-	-	18	-	18
Domestic Other	-	7	6	-	-	13	4	17
Total final a/	4	16	30	-	-	50	7	57
Generation	9	3	3	3	2	20	-7 b/	(13) c/
Total primary	13	19	33	3	2	70	-	(70) d/

a/ The total row is not in the original unit but is added here for clarity
b/ Positive sign is given in original
c/ No entry in this position in the original
d/ Total final energy (57 EJ) is repeated in this position in the published table.

239. As the foot-notes to the above table indicate, changes have been made to some of the total figures in the table in order to show up the characteristics of its underlying structure more clearly. For the same reason, the figures have been rounded from trillion BTU (BTU x 10^{12}) and re-defined as exajoules (joules x 10^{18}). This table is used for publishing data for past years.

240. The same structure of table, usually completed by rows for production and trade, is often used as a framework for reporting projections into the future and may be used as a basis for making very broad-brush projections. The subsequent tables in this section reflect and synthesize the practices of two major oil companies (Shell International and BP Oil), work carried out by the Energy Research Group (ERG) of Cambridge University (England) for the Conservation Commission of the World Energy Conference, the statistical work of the Workshop on Alternative Energy Strategies (sponsored by Massachusetts Institute of Technology), and the accounting framework used by the Energy Commission of the French planning commissariat (Commissariat Général du Plan).

241. It has been pointed out previously that forecasts usually proceed by assessing the likely amounts of consumption of each source of energy by each main sector of final use and then estimating, with appropriate judgements and assumptions about the inputs likely to be needed by the transformation industries in order to meet the projected levels of final use, the required amounts of primary energy either from indigenous or imported sources. The following bottom up complete (but fairly aggregated) balances illustrates such a framework.

A bottom up energy balance adapted to energy forecasting

(In terajoules)

Flow \ Source	C	O	M	N	H	E	Total
Industry	10	-	5	-	-	20	35
Transport	-	5	-	-	-	5	10
Domestic and other	100	-	5	-	-	15	120
Total final demand	110	5	10	-	-	40	165
Generation	-	90	-	15	15	-40	80
Total primary demand	110	95	10	15	15	-	245
Indigenous production	100	-	10	15	15	-	140
Imports	10	95	-	-	-	-	105

Key: C, coal; O, crude oil; M, methane or natural gas; N, nuclear; H, hydro; E, electricity; T, total energy.

242. In this balance, the demand by each final use sector for each fossil fuel and for electricity (in total) are entered, but the demand for electricity by final use sectors cannot be split between nuclear, hydro and classical simply because all types of power station normally feed into a unitary distribution system for electricity. The next step is to apportion the total demand for electricity by all final sectors together between nuclear, hydro and fossil fuel stations. This can be done on the basis of the existing and planned capacity and fuelling of each type of station (together with assumed or postulated future output, by type of station, if the projection exercise extends into years beyond existing power stations building plans) and assumed generation efficiencies.

243. In the above table, the opportunity cost basis is used for evaluating the primary fuel equivalent of nuclear and hydroelectricity and the efficiency of classical stations (taken, for simplicity, as 33%) has been applied to nuclear- and hydroelectricity. The actual procedure is simple in this case. In the generation row, double the electicity figure (2 x 40 TJ = 80 TJ) is entered in the total column. This last figure represents the waste heat lost in generation. The sum of the last two figures (40 + 80 = 120 TJ) is then the total quantity of primary energy required - on the stated assumptions - to generate the 40 TJ of electricity.

244. One of two assumptions is needed for the next step. Either the share of nuclear/hydro or the share of fossil fuelled generation is postulated, and the other type of generation is then assigned the balance of total electricity demand (on a primary energy input basis). For simplicity in this example, all the fossil fuelled stations are assumed to be oil burning.

245. The derived energy inputs to generation are then added to the total demand for final use in order to arrive at the row for total primary energy demand. The entry of 80 TJ in the total column of the generation row is all that has to be added to the 165 TJ of total final energy use because the latter figure already contains the electricity output associated with the 80 TJ generation loss. The last step is to subtract the row of indigenous production in order to derive the level and energy mix of the demand for imports (in the present series of examples).

246. The actual forecasting process is much more complex than this, particularly at the stage of projecting use within each final use sector, and the present Manual is not the place to describe or discuss all the details and complexities. The purpose of the preceding simplified description is to show how the bottom up balance provides a coherent and clear framework for reporting the results of more sophisticated longer-term projections and for making short-term forecasts. 61/ The major oil companies who kindly made available copies of their operational forecasting balances use frameworks of essentially this structure, but with much more detail on individual petroleum products and on types of use or user of particular importance in the oil market.

247. One of these company balances provides for the possibility of greater flexibility in illustrating the assumptions about electricity generation efficiencies as between nuclear, hydro and classical stations, by including two rows for generation. One row is used to apportion total final demand for electricity (and not, at this stage, its estimated total primary energy requirement) between energy sources, and the second row is then used for attributing to each source a loss reflecting the assumed generation efficiency. The efficiencies used may reflect the different approaches to quantifying the primary energy equivalents of nuclear on the one hand and hydro on the other, and

they can also reflect the higher efficiencies associated with combined heat and power production in thermal stations where this is important. This variant of the balance is shown below. The generation efficiencies used are 37% for classical, 33% for nuclear and 83% for hydro. For simplicity, this balance begins with the row for total final use since this is taken to be unchanged by the different assumptions made about power station efficiencies.

Energy forecasting balance: a variant

(In terajoules)

Flow \ Source	C	O	M	N	H	E	T
Final demand	110	5	10	-	-	40	165
Generation:							
Output	-	30	-	5	5	-40	-
Loss	-	50	-	10	1	-	61
Total primary demand	110	85	10	15	6	-	226
Production	100	-	10	15	6	-	131
Net imports	10	85	-	-	-		95

Key: See table following paragraph 241.

248. The preceding balances have ignored the losses on oil refining or, alternatively, these losses have been disregarded as insignificant compared with the uncertainties associated with the (hypothetical) projections. If the projections cover only a few years ahead, all the figures are likely to be more reliable and such losses, together with losses in distribution, in solid fuel (including coke) manufacture and use in auxiliary equipment by the energy industries cannot be ignored. One or more rows may be introduced to cover these flows. In a short-term projection the inclusion of refinery fuel and loss is conceptually important in order to put consumption of petroleum products on to a strictly primary energy (i.e. crude oil) input basis.

249. Alternatively, separate rows may be introduced for refineries and for any other relevant transformation industry. The same procedure is then followed by entering the final demand for a derived energy source in the corresponding transformation industry's row with a negative sign, and entering the appropriate primary fuel input(s) to that industry in the appropriate column with positive signs; and the corresponding transformation loss for that industry in the total column. In the following balance, oil refining (R) and gas manufacture (W) have been introduced and a row has been added for exports. The output from the transformation sector must now be sufficient to provide the exported quantity in addition to that demanded by the inland markets. A single row has been used for

each transformation industry and a uniform efficiency of 33% has been assumed for all forms of electricity generation.

Enlarged energy forecasting balance

(In terajoules)

Flow \ Source	C	O	R	M	W	N	H	E	T
Final demand	100	-	-	10	12	-	-	40	162
Generation	-	-	90	-	-	15	15	-40	80
Refineries	-	100	-95	-	-	-	-	-	5
Gas plants	10	-	4	-	-12	-	-	-	2
Total inland primary demand	110	100	-1	10	-	15	15	-	249
Export demand	-	-	1	-	-	-	-	-	1
Indigenous primary production	100	-	-	10	-	15	15	-	140
Imports	10	100	-	-	-	-	-	-	110

Key: See table following paragraph 241; also, R, oil refining; W, gas manufacture.

250. In the above balance, final demand for coal has been cut by 10 TJ and for petroleum products by 5 TJ, but demand for energy has been met by an additional supply of 12 TJ of manufactured gas (which would almost certainly be used more efficiently by final users than the solid fuel they burnt previously), and there is now an export of 1 TJ of petroleum products. To keep the illustration simple, no row has been added for energy industries' own use or for distribution losses. In principle there ought also to be a row for stock changes but in practice such a row is often not provided in forecasting balances unless they only cover a few years forward from the base year.

E. A multi-purpose balance

251. If the forward look bottom up balance is complete with rows for indigenous production, exports, stock changes and imports, and if it is inverted (not in the formal sense of matrix algebra - which is not possible or appropriate) and if the signs are changed for the transformation section, then we have a type VI balance as shown in paragraph 216 above. The following table is the inverse (in the simple arithmetical sense) of the table in paragraph 249, with the imports and production rows interchanged and the signs changed.

Inverse of forecasting energy balance

(In terajoules)

TJ

Flow \ Source	C	O	R	M	W	N	H	E	T
Primary production	100	-	-	10	-	15	15	-	140
Imports	10	100	-	-	-	-	-	-	110
Exports	-	-	1	-	-	-	-	-	1
Total supply of primary sources	110	100	-1	10	-	15	15	-	249
Gas plants	-10	-	-4	-	+12	-	-	-	-2
Refineries	-	-100	+95	-	-	-	-	-	-5
Power stations	-	-	-90	-	-	-15	-15	+40	-80
Total final use	100	-	-	10	12	-	-	40	162

Key: See tables following paragraphs 241 and 249.

252. As mentioned previously, rows should be added for the energy industries' own use, distribution losses and stock changes, and it is also desirable to split total final use into energy and non-energy purposes. The United Kingdom balance provides an example of a fairly disaggregated balance of this form and structure. Until 1977 it aggregated all petroleum products into a single column, but from 1978 it showed four broad groups for such products. It still gives only a very limited analysis of the final use sectors but greater detail on these (both in original units and in energy accounting units) can be found in supporting tables. The proposed new ECE (Geneva) balance is an example of a more detailed balance with the same structure and with generation split between types.

253. Matrix-type balances in which the inputs and outputs of the transformation industries are recorded in one row for each industry, with opposite signs for the inputs and outputs, have the dual advantage of being not only concise and economical in the presentation of data for past periods, but also directly appropriate (when inverted) to the presentation of projections for the future. The number of transformation industries and energy source columns can be varied according to the availability of data, the relative importance of energy sources and industries in any particular country and the level of aggregation or disaggregation needed in any particular analysis. 62/ At any level of disaggregation, a more highly aggregated balance can readily be produced from the fuller balance. Following is a collapsed version of the above balance distinguishing only fossil fuels, primary and total electricity:

Collapsed energy balance

(In terajoules)

Flows \ Sources	Fossil fuels	Electricity Primary	Electricity Total	Total energy
Primary production	110	30	-	140
Net trade	+109	-	-	+109
Total primary supplies	219	30	-	249
Power stations	-90	-30	+40	-80
Other energy industries' own use and all losses	-7	-	-	-7
Total final use	122	-	40	162

RECOMMENDATIONS:

(21) Overall energy balances should be constructed in matrix form with the following characteristics:

Columns show energy sources (energy commodities)

Rows show flows from origins to uses of energy (energy transactions)

Separate sub-matrices show, respectively:

(a) Supplies of primary sources and equivalents;

(b) Transformation inputs (with negative signs) and outputs (with positive signs); transformation losses in the total column (with negative signs); energy industries' own use; transmission and other losses;

(c) Final uses.

254. The number of columns and rows to be included depends on whether one is preparing a desk worksheet or a balance for presentation to energy policy analysis or for some other purpose. At desk level the rows and columns should be sufficient in number for drawing up a complete statistical statement of all economically significant flows from energy sources to final energy users, even if all the required data are not readily available. In this way the importance of filling - or the acceptability of leaving blank - the gaps identified can be assessed. Missing data may leave no choice at least in the short term, but acceptance of a higher level of aggregation than the level of detail initially sought. If, when all the desired information is available, the completed disaggregated balance is more detailed than necessary for some purposes, aggregation to higher levels is - as mentioned above - always possible, but disaggregation - which may be needed for other purposes - is not possible unless the more detailed data were collected and compiled in the first place.

255. After identifying all the rows and columns needed for a national overall energy balance, the available data should be assembled, initially in natural original units of measurement, in their respective columns of the overall balance worksheet. This stage amounts to compiling energy commodity balances using the standard set of side headings decided upon for the overall energy balance. At this stage of compilation, the existence of an input of a particular type of energy to a transformation industry and of an output of the <u>same</u> type from the <u>same</u> transformation industry may be traced. If this occurs, the size of one or the other, or of both the flows, may be so small as to be adequately recorded in a foot-note whilst showing only the net input or net output in the commodity/industry cell affected. If the size of one or other of the flows is such that both should appear explicitly in the main balance, this may readily be achieved by splitting the row and/or column that contain the cell affected by the two flows so as to show separately each flow.

256. In the case of the less-developed countries, balances should as far as possible be structured following the recommended principles and could usefully show in the columns at least the following energy sources:

Coal
Firewood
Charcoal
Bagasse
Other vegetable waste
Other (e.g. dried dung)
Crude petroleum (if appropriate)
Natural gas (if appropriate)
Petroleum products
Other sources (e.g. heat from renewable sources, to be specified separately or at least to be listed in a foot-note)
Hydroelectricity
Other electricity (distinguish nuclear, if important, and list other sources in a foot-note)

The rows of such balances should contain at least the following items:

Primary production
Imports
Exports
Total supplies of primary sources and equivalents

Transformation:
- Refineries (if appropriate)
- Power stations
- Other (to be specified)

Final energy use:
- Agriculture) Distinguish "market" and "traditional" sectors,
- Industry) if appropriate
- Transport
- Domestic and other

"Industry" could be divided into, for example, sugar manufacture, other food and beverages, cement, petrochemicals and other, as may be appropriate for each country.

257. If stock data are available, e.g. for crude oil or petroleum products, a row for stock change should be inserted after "Exports". As was mentioned previously, major oil producing countries that export a large part of their output may, at least in their national balances, locate exports as one of the final uses of energy. Further, given the difficulty of splitting bunkers between nationally and foreign registered vessels, so that true exports cannot be clearly separated from domestic sales, some countries may feel that, at least in their national balance they should classify bunkers as part of the final use.

258. In the case of the more developed countries, the columns should distinguish separately as many primary and secondary energy sources as are significant in each country, whether in trade or as indigenous production. There should be as many of the following rows as are appropriate for the particular country:

Primary production
Imports
Exports
Bunkers
Stock change (Rise-Fall+)
Statistical difference
Total available inland supplies

Transformation:

Coke ovens
Blast furnaces
Gas plants
Other solid fuel process
Power stations:
Public supply
Other
Combined heat and power production
Heat production
Refineries

Other energy producers (to be specified or at least listed in a foot-note)

Total

Energy sectors' use and loss:

Coal mines
Coke ovens
Gas plants
Other solid fuel processors
Power plants
Heat plants
Crude and natural gas producers
Refineries
Other energy structure (see note in brackets above)
Total

Distribution losses
Non-energy use
Final inland use

The subdivisions of final use are considered in chapter VI below.

259. The Statistical Office of the United Nations proposes to publish an overall energy balance with the degree of detail shown in the table that follows. This balance contains two features not so far discussed in this Manual but which can help in the process of familiarization with the matrix structure of overall energy balance. The row "Energy converted" shows the net input to, or net output from, the energy transformation industries. A net input carries a negative sign and a net output is shown by a positive sign. The row "Transfers" is for recording purely institutional changes in the distribution channel through which a particular energy source is delivered to final energy users (e.g., synthetic natural gas may be an output of the petroleum refining industry but may be distributed through an existing natural gas grid, so that the flow that starts in the column for petroleum gases may need to be transferred - without any process loss - to the natural gas column). A much simpler version of this balance would be sufficient for developing countries, and a separate balance could (if desired) be constructed for traditional and non-conventional energy sources. Examples of such balances are shown in annex VIII.

F. Other balance problems

1. Double-counting

260. Double-counting might seem to be something to be avoided at all costs, and one of the main objectives in considering alternative structures for an overall balance was the elimination of double-counting between primary and derived energy sources. But "double-counting" is a slightly ambiguous concept. For some purposes it may be legitimate to count twice in a given total two components one of which already includes the other. When relating an industry's capacity to its output, for example, it is right to consider that industry's total output even though part of that output may represent recycling. This principle needs careful interpretation in the context of energy balances, as is illustrated in the next two cases.

2. Pumped storage generation

261. Countries with hydroelectric power solve the problem of the non-stockability of electricity by the ingenious technique of using cheap off-peak fossil fuel or nuclear-based electricity to drive specially designed hydropower stations in reverse, thereby pumping water from lower to higher levels overnight. The following day, the stored water flows downhill and drives the hydropower alternators. Water is, in effect, used as the storage medium for electricity.

262. It might be argued that this operation should be treated as a stock change in an energy balance. This would not be practicable in an annual balance because the difference in the water level between the beginning and end of the year would be influenced by rainfall, evaporation and other factors besides the pumped storage

STATISTICAL OFFICE OF THE UNITED NATIONS

OVER-ALL ENERGY BALANCE SHEET (revised)

English only

Units: Terajoule

Country:

Year:

	TRANSACTIONS \ COMMODITIES	Hard coal, brown coals, lignite	Briquettes and cokes a/	Other solid energy sources ("non-commercial") b/	Crude petroleum, other inputs to petroleum refineries, natural gas liquids	Light petroleum products c/	Heavy petroleum products d/	Other petroleum products e/	LPG and other petroleum gases f/	Natural gas g/	Derived gases h/	Nuclear, hydro and geothermal electricity: Conventional fuel equivalent	Nuclear electricity (Physical energy input)	Hydro and geothermal electricity (Physical energy input)	Electricity	Steam and hot water i/	TOTAL ENERGY: Conventional fuel equivalent	TOTAL ENERGY: Physical energy input
1	Production of primary energy																	
2	Imports																	
3	Exports																	
4	Marine bunkers																	
5	Stock change																	
6	Total energy requirements*																	
7	Energy converted																	
7.1	Briquetting plants																	
7.2	Coke ovens and coke plants																	
7.3	Gasworks																	
7.4	Blast furnaces																	
7.5	Petroleum refineries																	
7.6	Electric power plants**																	
7.7	Heating plants***																	
7.8	Other conversion industries																	
8	Transfers																	
9	Consumption of energy sector																	
10	Losses in transport and distribution																	
11	Consumption for non-energy uses																	
12	Final consumption																	
12.1	Manufacturing industry, mining, and construction																	
12.1.1	Iron and steel industries																	
12.1.2	Non-ferrous metal basic industries																	
12.1.3	Chemical and petrochemical industries																	
12.1.4	Other manufacturing industries, mining and construction																	
12.2	Transport																	
12.2.1	Road																	
12.2.2	Rail																	
12.2.3	Air																	
12.2.4	Inland and coastal waterways																	
12.3	Households and Other Consumers																	
12.3.1	Households																	
12.3.2	Agriculture																	
12.3.3	Other consumers																	
13	Statistical differences (6+7+8+9+10+11-12)																	

* Gross consumption of primary energy and equivalents.

** Public power plants and power plants of self-producers.

*** Including combined heat and power (CHP) plants.

a/ Hard coal briquettes (patent fuel), brown coal briquettes, lignite briquettes, peat briquettes, coke oven coke, gas coke, brown coal coke, coke breeze, low temperature coke and char. Includes coal derivatives and by-products.

b/ Peat, fuelwood, charcoal, bagasse, dung, tar, wood wastes, vegetal wastes, pulp and paper industry wastes, municipal and other wastes n.e.s.

c/ Aviation gasoline, motor gasoline, white spirit, industrial spirit, naphthas, jet fuels, kerosene.

d/ Distillate fuel oils, residual fuel oils.

e/ Bitumen, lubricants, petroleum waxes, petroleum coke, petrochemical feedstocks, refinery fuel n.e.s., other petroleum products n.e.s.

f/ Liquefied petroleum gases (LPG), refinery gas, ethane.

g/ Natural gas, colliery methane.

h/ Gasworks gas, coke oven gas, blast furnace gas. Includes production of substitute natural gas (SNG).

i/ Includes geothermal heat distributed as such to consumers.

activity. Even if these influences were absent, the annual difference in water level would give no indication of the extent of redistribution through time of electricity production for final use.

263. There are two other ways in which pumped storage can be treated. The first is to record the output from pumping as part of the electricity supply and to record the input to pumping as part of the energy industry's own use. The second is to exclude the output from production (since it is merely some earlier output made available for final use later) and to record only the net input to (or loss on) pumped storage as part of the energy industry's own use. On balance the latter basis is to be preferred.

264. Of the countries whose balances show pumped storage, those for the Federal Republic of Germany, Sweden and the United Kingdom, together with SOEC and ECE (ABGES), double-count the output; Austria, France (CEREN) and Portugal do not double-count.

RECOMMENDATION:

(22) Electricity output from pumped storage should not be added to electricity produced by other methods (because the latter already includes the electricity that is redistributed through time by means of pumped storage) when compiling an energy balance. The difference between the input to and the output from pumping should be treated as part of the electricity industry's own use.

3. Oils returned to refineries

265. Contaminated products and salvaged lubricants that are returned for cleaning and/or blending do provide part of the input to the refining activity, even though such products form part of the output of a previous accounting period. The same is true of naphtha or other materials returned from the petrochemical industry. This is another instance where an internally consistent energy balance could be produced either excluding, or including (i.e. double counting), these returned products. In contrast to the case of pumped storage (in which a given quantity of plant is either pumping or generating), refining capacity is devoted to handling both first time processes and reprocessing, and the output from both types of processing is available for use during the accounting period. Hence in the present case the double-counting basis is to be preferred. For completeness, refinery fuel should also be counted both as part of output and of the petroleum industry's own use.

RECOMMENDATION:

(23) Materials returned to oil refineries should be included as inputs to refining, even though such materials have previously been accounted for in refinery output. Refinery fuel should also be included both as part of output and as part of own use.

4. Original units and common units

266. It is often difficult to relate the data in an energy balance to the raw data published in detailed tables about the separate energy industries. It is very

convenient when balances are published in duplicate, with one balance showing the data in original units and the other giving the data in the common accounting unit. Even in such cases, however, the relationship between the original balance data and the original industry data can be unclear. The French World Energy Conference (WEC) balance and the earlier French (CEREN) balances are most helpful in publishing one balance without data but with every (or nearly every) cell designated by a number, and a separate list gives the definition and/or source of each figure that appears in the completed balance.

267. An alternative way of showing this relationship would be to include with tables of energy industry statistics one table for each industry showing the derivation of the data as used in the balance from the data as ordinarily published about the industry.

RECOMMENDATION:

(24) The relationship between the original-unit data as used for an energy balance and as published in the usual statistics about each energy industry should always be made clear.

5. Conversion factors

268. An earlier recommendation (20) calls for clarity in stating the conversion factors used and in describing the route followed when expressing original quantities in terms of the common accounting unit. The balances of Austria (OSZ) and Italy (MIC) show at the top of each column (or at the end of each row when a table uses rows for energy sources) the conversion factors used. This is very convenient as an aid to linking the original and common accounting units particularly when, for example, electricity is expressed as heat energy in one table and in primary energy input terms in another table. The Italian table gives foot-notes to explain departures from the average factor in the cases of particular flows. Other balances (Federal Republic of Germany, Sweden, the United Kingdom, ECE, OECD and SOEC) are accompanied by separate detailed lists of conversion factors.

RECOMMENDATION:

(25) Energy balances should contain in the column headings for each energy source the average conversion factor (appropriate for expressing the original units in (or underlying) that column in terms of the common accounting unit as shown in the balance). Such average factors should be complemented in foot-notes or accompanying text, with clear descriptions of the routes and stages followed in any conversions that are not adequately defined by the average factors.

6. Number of digits

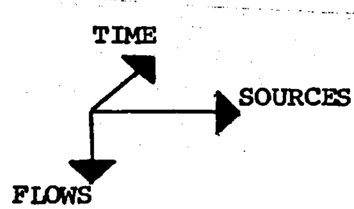
269. Energy balances are intended to give a coherent visual description of the many interrelated flows in the energy supply economy. Balances may contain up to 1,000 cells of information (about 25 separate columns and up to 50 rows, including types of final user). Even when they show many fewer, nothing is gained by displaying more than six digits at most, and more generally four or five digits in

any cell (including total cells). A few balances publish more digits than are necessary for the purpose of the balance and possibly more than the quality of the raw data warrant. Energy balances should in principle only show figures of up to four or five digits in general, with six digits as the exception.

270. There remains for consideration the detail that may need to be listed and the nomenclature to be used in the row and column headings. These matters are the subject of chapter VI.

7. Matrices and time series

271. A matrix type of overall energy balance that shows energy sources in the columns and energy flows in the rows is well suited to showing a fairly complete picture of energy supplies, transformations and uses in a single time period, normally a year. For a time series, a set of such balances is necessary, one for each year. The complete set of data for a period of years may thus be regarded as forming a three-dimensional figure whose dimensions show, respectively, energy sources, energy flows and time, thus:



272. It is a simple matter to derive time-series tables in two dimensions from such a block of data by making either vertical or horizontal slices through it. A vertical slice will show the energy commodity balance for a selected energy source (e.g. natural gas) in each of the years for which data have been compiled either in original units or in the common accounting unit or in both. A horizontal slice will show for each year the quantities of each separate energy source and (if expressed in the common accounting unit) all sources together for the selected flow (e.g. imports).

273. Such time-series tables in original units may of course have provided at least some of the basic data from which the standard energy commodity balances for each energy source were themselves compiled. It is however likely that not all the energy commodity balance data was readily available for fitting into the standard side headings without adjustment of one sort or another. Standardized time series tables that are fully compatible with (by being derived from) the overall energy balance are very convenient for many analytical purposes, such as the study of changes in the mix of different energy sources in a total flow and changes in the pattern of use for a given energy source.

VI. CLASSIFICATIONS

A. General

274. Standard international classifications exist or are envisaged for commodities (ICGS), industries (ISIC) and trade (CCCN and SITC), and broadly similar classifications exist for EEC countries (NIPRO, NACE and NIMEXE respectively) and for CMEA countries (GCP). 63/ A very large number of, and probably most, countries have their own national classifications designed to meet their own particular needs and differing to some extent, from the international standards.

275. The various existing international classifications came into being because of the need for consistent treatment of commodities that are subject to customs duty (CCCN), and then, more generally, for consistent classification of all commodities entering international trade (SITC), whilst at the same time having a basis for international comparison of national statistics on separate industries (ISIC). These different origins resulted in different approaches to the drawing-up of each classification. CCCN and SITC had to be based on physical characteristics of commodities that customs officers could recognize merely by looking at the goods in question. ISIC was designed to serve as a framework for the collection and analysis of statistics about the inputs to and outputs from industrial establishments and is therefore based on descriptions of activities.

276. As economic analysis became more sophisticated, there was a need to be able to relate the commodity output of industries to imports and exports of the same commodities. There was therefore a need to relate the commodities in SITC (and CCCN) to the industries in ISIC, and the ICGS seeks to do just that. The resulting detail is however too great for some purposes, and the System of National Accounts, (SNA) resorted to a greatly simplified version of the ISIC, leaving to countries the responsibility of assigning commodities to industries. A more recent attempt to regroup the headings of SITC into categories of relevance to economic analysis is the BEC.

277. Besides these more general purpose international classifications there are more specialized international classifications of transport statistics (CSTE), occupations (ISCO) and other subject areas more or less remote from energy (such as research and development, and education).

278. The new importance that energy has acquired in the past five years or so has introduced a new facet into this already complex field of classifications. This present Manual considers some particular aspects of classification that arise directly out of the preceding chapters.

B. Current treatment of "Energy"

279. The SITC conveniently groups together all fossil fuels, lubricants and the like into its Section 3, "Mineral fuels lubricants and related materials", but the apparent comprehensiveness is incomplete. Uranium and similar ores are in Division 28, "Metalliferous ores and metal scrap", nuclear fuels and residues are in Division 52, "Inorganic chemicals" and firewood is in Division 24, "Cork and wood". Apart from this scattering of energy sources among three different sections, the detail of the classification has its own short-comings. Just because

it is a classification designed for international trade, commodities that do not normally enter such trade are not provided for, and some that do cannot be subdivided by characteristics that are not recognizable visually. Steam and hot water are not listed, and electricity is not subdivided by type of generation (nuclear, other thermal, hydro etc.).

280. In ISIC, and so ICGS (which distributes the goods in SITC between the industries of ISIC), this scattering of energy sources is even more marked. Firewood is in Division 12, "Forestry and logging"; uranium extraction is under Division 23, "Metal ore mining"; peat, which is part of Section 3 in SITC, is in Division 29, "Other mining"; nuclear fuels are part of Division 35, "Manufacture of chemicals and chemical petroleum, coal, rubber and plastic products". In this last division two other groups cover, respectively, 353, "Petroleum refining" and 354, "Manufacture of miscellaneous products of petroleum and coal". This last group covers coke, briquettes and lubricants. Coal mining and crude petroleum, together with natural gas production, each has its own group within Division 2, "Mining and quarrying".

281. In contrast to SITC, ICGS is able to, and does, distinguish between electricity made in conventional thermal, nuclear, hydro, gas turbine, internal combustion engine and other (e.g. geo) stations. Interestingly, ICGS not only has a class for "Steam and hot water supply" but subdivides this into "Steam, hot water, hot air" and "Cooled air".

282. The only United Nations classification that at present brings together all - or nearly all - forms of energy into a single category is the BEC. This classification is based upon the three broad economic categories used in national accounts and input/output, namely capital goods, intermediate goods and consumption goods. Within intermediate goods it has a category "Fuels and lubricants" and applies to this the same split as it does to other intermediate goods, namely between primary and processed goods. The headings are summarized below:

Fuel and lubricants

- Primary
  - Fuel wood
  - Coal and lignite
  - Crude oil
  - Natural gas
- Processed
  - Charcoal
  - Briquettes
  - Motor spirit
  - Other petroleum products
  - Manufactured gas
  - Electricity

283. Nuclear fuels whether in their raw or fabricated state seem to have been omitted from BEC. Steam and hot water do not appear because they are not fuels.

284. NACE and NIPRO differ fundamentally from the United Nations classifications in two ways. NACE and NIPRO provide a separate and complete Class 1, "Energy and water" and within that class (and all other classes), the commodity classification within each industry lists successively first the unprocessed and then the processed forms of each commodity. In a very simplified form the structure is as follows:

Coal mining

- Coal
- Coal briquettes
- Lignite
- Lignite briquettes

Coke ovens

- Metallurgical coke
- Other coke
- Coke oven gas
- Other coke oven products

Crude oil and natural gas production

- Crude oil
- Natural gas
- Natural gas liquids
- Bituminous rocks and shales

Petroleum refining

- Light oils
- Medium oils
- Heavy oils
- Lubricants
- Other petroleum products

Extraction and treatment of nuclear fuels

- Uranium ore
- Thorium ore
- Uranium and thorium concentrates
- Fissile and breeder isotopes
- Fuel elements

Electricity production and distribution

Public supply -

Conventional thermal
Geothermal
Hydro
Nuclear
Irradiated fuel elements
Heat

Autoproduction -

Conventional thermal
Hydro
Nuclear
Irradiated fuel elements

Gas works

Works gas
Coke
Other products

Production of steam, hot water and compressed air

Combined production of two or more types of energy

The petroleum products and nuclear materials are listed in NIPRO in very considerable detail, and electricity is subdivided according to the type of fossil or fissile fuel used.

285. Of the existing international classifications examined, NACE/NIPRO is the one most suited to the compilation of a fairly complete and "articulated" set of statistics on the production and use of energy, and it deserves closer study in the light of this present report's recommendations on desirable features of energy statistics. The full classifications of NACE and NIPRO for "Energy and water" are given in annex V.

286. One of the particular needs in a standard classification of energy commodities is an agreed nomenclature for gaseous and liquid petroleum products. All the listings used in the national and international and institutional balances, and in the international standard classifications are very similar but nevertheless contain differences in how they treat or designate or define particular products (e.g. natural gas liquids). The SOEC has published a very useful booklet "Definitions of oil and oil products". 64/

RECOMMENDATION:

(26) Existing classifications and definitions of crude hydrocarbons and derived products should be examined with a view to establishing an agreed international set of designations, groupings and definitions.

C. Final energy uses

287. None of the United Nations or SOEC classifications goes sufficiently "downstream" for the full range of purposes of energy balances. When discussing such balances as a framework for forecasting, it was pointed out that usually the "bottom up" balance is used, with a considerable amount of effort going into the analysis of final uses. This analysis may be approached in two ways. The first is through the concept of useful energy and the second is through the consideration of a use-analysis of energy supplied.

1. Useful energy

288. Useful energy is the energy effectively transformed into useful work in the equipment and processes of final energy uses, such as the work obtained from a motor car, or the light obtained from a filament bulb or a fluorescent tube, or the heat obtained in the steam produced by burning fossil fuel beneath a boiler. These amounts of useful work reflect the combined effects of the theoretical efficiency of the appliance or the equipment or the process, and its intensity and mode of use. An appliance working under what its maker would regard as optimal conditions will have a higher efficiency than the same appliance operated by a more demanding or a more careless person. The efficiency of space heating equipment is similarly difficult to measure and even to define, since much will depend on the insulation of the walls, windows, floor and ceiling of the space to be heated and on the number of times that accumulated heat is allowed to escape through openings such as doors and windows.

289. It is nevertheless necessary to recognize the very different average efficiencies with which different energy sources can be converted into useful work. These average efficiencies reflect the range of uses for which each source is most suitable as well as the factors already mentioned. This is not the place to examine these matters in detail but to give a very broad idea of orders of magnitude, some, the following figures show the range of efficiencies in question: 65/

Fuel	Percentage efficiency	
	Range	Mean
Solids	20-80	55
Liquids	15-19	45
Gases	60-65	65
Electricity	80-95	90

290. These widely different efficiencies need to be taken into account in forecasting future demand for energy, because energy users ultimately demand useful energy, and possibilities for substitution between energy sources is really only

relevant at the level of useful energy (in the sense that it is only at that level, within a given use, that substitution of 1 joule of one type may be replaced by 1 joule of another type of energy). 66/ Such substitution is of course limited by the stock of fuel-using equipment at any time.

291. Estimation of these overall efficiencies for each fuel is not easy except in a rather rough and ready manner. The stock of equipment itself gives no indication of its intensity or manner of use, and collection of the necessary data at the level of users can be a long and expensive business. Even the roughest estimate nevertheless changes substantially the relative importance of each energy source within the final use sector, largely because of the very high efficiency of electricity in the uses to which it is put compared with the efficiencies of the fossil fuels in the uses to which they are put.

292. The published Swedish energy balance is accompanied by a broad analysis on a useful energy basis of the relative shares of each energy source in total energy consumption. The Norwegian energy balance goes further and includes as an integral part of itself such an analysis. Although the United Kingdom does not yet publish regularly statistics on useful energy, considerable detail on final consumption of useful energy is given in Energy paper 29 (1978). SOEC has published energy balance for 1977 and 1978 showing final energy use by purpose on the basis of heat (or energy) supplied and useful energy. Jamaica is intending to include data on both forms in its national energy accounting system. India publishes overall energy consumption estimates, including non-commercial sources, in "coal replacement tons" (which weight each source according to its estimated useful energy yield).

RECOMMENDATION:

(27) National and international statistical offices should consider publishing estimates of the quantities of useful energy consumed by each final consumption sector. Such estimates should be accompanied by details of the methodology used.

2. End-use by purpose

293. An alternative to producing figures on useful energy - and indeed a necessary stage in producing such figures on a reasonably reliable basis - is the analysis of deliveries of energy according to the purpose for which each type of energy is used within each final use sector. Such an analysis is also a step towards analysing end-use between substitutable and non-substitutable purposes.

294. Such an analysis is most straightforward for the sector that is final in the national account sense, viz. domestic users. In this sector, an analysis that could, in principle, be made is as follows:

Space heat and ventilation
Water heating
Cooking
Domestic motive power (refrigerators, freezers, cleaners, polishers, mixers, garden and other tools, and other appliances with electric motors)
Lighting
Other (e.g. television, radio, record and tape equipment)

This sort of information can be very time consuming (and costly) to obtain.

295. The transport sector may be analysed most simply according to the modes, land, sea, air and water, or in greater detail thus:

Road

- Automobile
- Bus
- Taxi
- Lorry
- Motor cycle

Rail

- Passenger
- Goods

Air

- Passenger
- Goods

Water

- Inland
- Coastal

Pipeline

It will be recalled that ocean-going ships are treated separately as "Bunkers".

296. More refined subdivisions of transport might be considered such as according to inland/rural areas, distance travelled, engine or load-capacity of the mode and type of cargo carried. This field of analysis has already been covered by a special classification for the European region (CSTE) and is currently being studied by a Group of Experts on Transport Statistics of the Inland Transport Committee of ECE, and their work needs closer study in the context of energy balances. 67/

297. The commercial sector may be analysed on a basis somewhat similar to that suggested for the domestic sector but distinguishing only:

- Space heating, cooling and ventilation
- Water heating
- Motive power (lifts, office machinery and equipment)
- Lighting
- Other (if any)

298. The agricultural sector, which is of relatively small importance in most major industrial countries but is of considerable importance in other countries may usefully be analysed along the following lines:

Space heating and ventilation

Glass houses
Other (including dwellings)

Farm machinery and equipment
Lighting
Other

299. This is far too sophisticated a classification for the less developed countries whose agriculture will rely largely for its energy on animal draught power and human labour. Where powered machinery and equipment (e.g. small and medium sized tractors, irrigation and drainage pumps) exist, the appropriate headings may be used. The usefulness of attempting to quantify in an energy balance the large amounts of animate power used in most of the least developed countries needs to be decided on the basis of the purpose for which the balance is needed (e.g. to assess the future likelihood of animate power being replaced by fossil fuel or electricity).

300. The industrial sector poses the same sort of problem that was encountered when aggregation across fuels was discussed in chapter V. 68/ For any one energy source, it would be possible in principle to analyse use within industry according to (e.g.) the following split:

Space heating and ventilation
Water heating
Process heating
Motive power
Lighting
Other

301. This classification is insufficiently precise, however, because it says nothing about the temperature to which the water is heated. If it is turned into steam, the steam may itself be used for space heat and/or for process heat, or it may be used to drive a turbo-generator, and the resulting electricity may be used for any of the listed purposes. Differentiation between "steam raising" and "water heating" would help, provided the list is treated rigorously as a list of first uses of purchased energy sources.

302. Such an analysis would be illuminating but it would not show the total amount of energy used for each of the listed purposes. Such a complete analysis leads directly to the double-counting problem already met earlier in chapter V. Further, a complete analysis would require the inclusion of three types of non-commercial energy, namely, auto-produced electricity used on site, heat recovered from the exhaust from a first use of purchased energy, and (where it occurred) exothermic heat from chemical processes.

303. There is much to be said for a complete analysis of this sort but it would be best produced as a satellite table to the main energy balance. A full energy use analysis could, in principle, show the extent of (and give an initial impression of

the scope for) exhaust heat recovery within the industrial sector through "energy cascading". This means the initial use of purchased energy for producing high grade (i.e. high temperature) heat and using it "in cascade" for purposes each of which needs heat at a lower temperature than the immediately preceding purpose. (This does not mean that each stage in a manufacturing process can only have heat at a lower temperature than at the preceding stage).

304. Such cascading enables a given quantity of heat measured in joules to do more work in total, and it is a reminder that measurement of energy in joules (or in any other energy unit) tells one nothing about the quality or grade of that quantity of energy. Joules of heat energy are not substitutable for each other unless they are at the same temperature. (It should not be overlooked that energy used for lighting also yields space heat.)

305. The table below illustrates a complete analysis of first and subsequent uses of heat in a hypothetical industry. The analysis uses the structure of the basic energy balances with columns for energy sources and rows for uses of energy. As before, positive signs indicate a production, and negative signs a use, of energy.

306. Recovery of steam and heat are differentiated from the initial production of steam. Autogeneration with CHP is differentiated from electricity only generation. Exothermic heat is assumed to be produced in and recovered from a chemical process.

RECOMMENDATION:

(28) National statistical offices should consider constructing end-use analyses of the type illustrated in the attached table:

Hypothetical analysis of energy use in an industry

(Input - Output +: in terajoules)

Sources / Flow	Fossil fuels	Electricity	Initial steam	Hot Water	Recovered Steam	Recovered Heat	Net total	Recovered
Initial supply								
Purchased	+100	+20	-	-	-	-	+120	-
Exothermic heat	-	-	-	-	-	+10	+10	+10
Total	+100	+20	-	-	-	+10	+130	+10
Transformation								
Boilers	-100	-	+90	+8	-	-10	-12	-
Generating sets:								
CHP	-	+10	-40	-	+20	-	-10	+20
Other	-	+15	-40	-	-	-	-25	-
Total	-100	+25	+10	+8	+20	-10	-47	+20
Available energy	-	+45	+10	+8	+20	-	+83	+20
Final use								
Furnaces	-	-10	-	-	-	+5	-5	+5
Process heat	-	-10	-7	-	-18	+5	-30	+5
Space heat and hot water	-	-	-	+8	-	-9	-1	+8
Machine drive	-	-10	-	-	-	-	-10	-
Ventilation and cooling	-	-5	-	-	-	-	-9	-
Lighting	-	-5	-	-	-	-	-5	-
Chemical processes	-	-5	-	-	-	-	-5	-
Other	-	-	-	-15	-	-	-15	-
Losses	-	-	-3	-1	-2	-1	-7	-
Total	-	-45	-10	-8	-20	-	-83	+18

VII. OTHER ENERGY STATISTICS

A. General

307. As was stated towards the beginning of this report, an energy balance is or should be the core of any coherent system of energy statistics, even though most systems will have grown out of various independent sets of energy-industrial statistics. Countries will need to maintain much and probably most of their existing body of statistical data, covering as it will much more than is needed for energy balances, such as data on imports of energy sources by geographical origin, exports by destination, capacity of petroleum refineries and electricity generating stations, other characteristics of plants such as type of refining, and rates of utilization such as plant load factors. Much of this larger mass of statistical information will be required more frequently than annually, or for parts of the energy economy of great interest for particular and continuing purposes, such as short-term indicators of the output of smokeless fuels, or productivity of manpower in coal mining, or stocks of petroleum products at power stations. Nevertheless, countries and international bodies will need to re-examine their existing overall statistical systems to determine, in the light of the needs of energy balance construction, what series need to be redefined, dropped, merged or introduced, and whether by harmonizing concepts and coverage of some existing series, a smaller volume of original data can be made to serve a wider range of analytical purposes.

308. For their part, the international bodies will also need to consider how far existing international questionnaires can be harmonized and, hopefully, merged together into a limited number of multipurpose returns.

B. Shorter-period and regional balances

309. National and international statistical offices may wish to consider the desirability of producing at least simplified energy balances more frequently than annually, and for regions within countries and within larger geographical areas. The Netherlands already publish detailed balances each quarter, and the OECD and United Kingdom publishes quarterly simplified balances. France (CEREN) and Canada already produce detailed regional balances and CEREN is understood to be actively interested in monthly overall balances.

310. The shorter the time-span covered, the greater the likely influence of weather effects on demand for energy for space heating or cooling and for hot water. The demand for process heat may also be affected in the case of industries producing goods that are weather-sensitive, such as some types of clothing and foods. Demand for transport fuels may also be affected by weather. This is not as easy an area of analysis as it might seem and its further consideration is outside the scope of this present report.

C. Energy balances and input/output

311. Attention has already been drawn to the problem of comparability between concepts and coverage of flows and stocks in energy balances on the one hand, and in national accounts and input/output tables on the other. Further work needs to be done in this area. Whether or not such work could achieve full comparability in the near future, it should help towards the improvement of comparability between

industrial statistics on inputs of energy and outputs of goods and services. Such comparability is of great importance to current studies of the energy content of goods and services as one factor to be taken into account in making proposals for more economical use of energy in future decades.

312. A useful step towards identifying inconsistencies between energy data as presented in an energy balance on the one hand and in input/output tables on the other is to produce a transactions matrix in physical quantities: that correspond, in principle if not in practice, to the money values that are shown in existing matrices of transactions between industries, and between them and final consumers (in the national accounts sense). The next step is to recast in energy balance format the quantitative data thus assembled. 69/ (Attention has already been drawn to the problems raised by bunkers and inland transport energy use.)

313. Such an exercise is by no means trivial because many of the cells in an input/output table are likely to have been completed from value data whose quantity and price components may not be readily available. Other data in such a matrix are likely to come from sources that differ in coverage or concept from the sources used in compiling an energy balance. Such an analysis could usefully lead to the production of a triad of matrices showing respectively quantities, average unit values, and total cell values. Some money values in a transaction matrix (e.g. taxes, distribution costs) will have no associated quantities.

D. National acounts terminology

314. It is important to avoid confusion between the national accounts concepts of "intermediate" and "final" consumer and the energy balance concepts of "final energy use". Ideally the risk of confusion should be avoided if satisfactory terminology could be agreed upon, but this may not be easy to achieve.

315. A working paper of the Ad Hoc Meeting on Energy Economy and Efficiency in the ECE Region (ECE/AC.3R1/Add.1, dated 28 February 1977) entitled "Some conceptual, statistical and methodological questions" very understandably proposes the terms "Intermediate energy demand" and "Final energy demand", each having its appropriate national accounts, and therefore input/output, connotation. In its published balance, the United Kingdom studiously refrained from using the terms "final consumers", "final consumption" and "final demand", and hoped that by using the term "final energy consumption" all misunderstanding would be avoided. In this present report, the term "final demand" was convenient to use in the simplified bottom up forecasting balances. The term "intermediate" would be convenient when referring to the energy transformation industries, but the use of this term has so far been avoided in energy balances.

RECOMMENDATION:

(29) In order to avoid possible confusion between the meanings of "final" (and "intermediate") in national accounts, input/output and other economic analyses on the one hand, and in energy balances on the other, tables and texts that refer to the flows involving the energy transformation industries and/or final users of energy should always make clear what is meant by "final" (and - if the term is used - "intermediate").

E. Derived statistics

316. Energy balances will be all the more useful if they are accompanied by tables showing, for example, the percentage distribution of origins and uses within each energy source and for all energy sources in total, and the percentage split between energy sources within each major level of supply and use shown in the balance. What this amounts to is "percentaging" first the columns and then the main rows in the balance. Time series can then be built up from these percentage splits, and rates of change through time can be produced as a third type of commentary table. Examples of these sorts of derived tables may be found in the energy statistics published by Sweden and Norway, and some other countries.

317. More sophisticated derived statistics going somewhat beyond the scope of this particular report are published regularly by some countries (e.g. Austria and Poland) on the energy content of the output of industries or of commodities. Such tabulations may merely show the share of energy purchases in total purchases in each industry, or the direct input of energy per unit of value of output of each industry, or they may go further still and - using formal input/output analysis - show not only the direct but also the indirect "upstream" (and hence the total) energy content of the output of each industry or of each class of commodity or of each sector of final consumption (final in the national accounts sense).

F. Flow charts

318. The problems of making energy balances comprehensible to intelligent non-specialists have already been acknowledged by the recognition to use a presentation unit such as the TOE in addition to the terajoule. A further way of presenting the various flows and interdependencies in the energy economy is by means of a flow chart. In its simplest form this may amount to no more than drawing a series of boxes representing activities (such as oil refining, electricity generation, final energy use) and interconnecting arrows representing flows of crude oil, other fossil fuels, electricity and so on. Numbers may be attached to the arrows to indicate the size of each flow. (The percentaging of rows and columns in an energy balance is equivalent to making cuts vertically or horizontally in a flow diagram.)

319. A more striking diagram can be produced if the widths of the arrows are made proportional to the size of the flows. The diagram will be all the more effective if a different colour is used to denote each energy source. One of the first such coloured diagrams was published in 1956 in the Proceedings of the International Conference on Peaceful Uses of Atomic Energy. 70/ Another appeared in Laading's 1960 paper and in Guyol (1971). Among current examples of fairly detailed flow charts are those produced for the Nordic countries by the Scandinavian Boiler Engineers' Association and those published by the Netherlands Central Bureau of Statistics, the Department of Energy of the United Kingdom and by the OECD. The ECE published regional flow charts for a single year in its 1976 report already cited.

320. At least one of the major international oil companies and some of the international research bodies visited also produce flow charts. The Brookhaven/Julich team use a detailed black-and-white arrow flow diagram to describe precisely the energy system of each of the sizable number of countries they are studying, and as an aid to understanding the likely impact of future possible changes in parts of each system (e.g. new renewable energy sources).

321. Several of these published flow charts (e.g. Laading, Guyol, ECE, Scandinavian Association) show losses at the stage of final energy users. One Norwegian chart shows in addition the energy content of non-energy imports and exports. 71/

G. Energy and the environment

322. One of the advantages of the matrix-balance recommended in chapter V is that it shows explicitly heat emissions to the environment by the energy transformation industries. Elsewhere in this report it has been pointed out that heat losses occur at all stages of the energy-using process. Chapter VI discussed the possibility of extending the energy balance in order to show the useful energy effectively employed by final energy users. Nebbia (1975) and others have pointed out that even energy embodied in manufactured products (furniture, automobiles or buildings) is returned to the environment at some later - maybe much later - date when those products disintegrate through one means or another. Heat emission is only one of many factors influencing the quality of the environment (for worse or maybe, in cold climates, for better). The emission or dispersion of various chemicals may be of much greater importance than heat to those concerned with analysing and monitoring various facets of the quality of the environment. Nevertheless there is a statistical interface between energy and environmental statistics and this needs to be borne in mind by those working on both sides of this important frontier.

H. Interdisciplinary collaboration

323. Last, but by no means least, any system of energy statistics will be more efficiently produced and more widely used if it is the result of close and permanent consultation and active co-operation between the people in statistical, economic, technical and policy services who are concerned as producers or users with statistics as a basis for, and product of, work on energy policy formulation, implementation and appraisal.

Notes

1/ An exception was the interest shown by SOEC (Luxembourg), and more recently by OECD when preparing "Energy prospects to 1985" (1975).

2/ See for example NEDO (1974a) and (1975).

3/ See IFIAS (1974).

4/ *Ibid.* (1975).

5/ See, for example, NEDO (1974), Chapman, Leach and Slessor (1974), and Sroczynski and Szpilewicz (1977).

6/ See Wright (1974) and (1975), Bullard and Herendeen (1975), ECE (1976), Netherlands Central Bureau of Statistics (1976), and Longva (1977).

7/ See Leach (1975), Webb and Pearce (1975), and Common (1975).

8/ See CBI (1975) and Department of Energy of the United Kingdom (1976) and (1977).

9/ Strictly speaking, "power" is the rate per unit time at which energy is made available or at which work is performed.

10/ Exhaust heat, strictly speaking, contains only the direct energy cost. There are also all the indirect energy inputs to the extraction, preparation, transport and transformation processes. See chap. I, sect. C.

11/ See chap. V, sect. D. The International Energy Agency uses the crude oil equivalent of petroleum products as an operational concept in implementing the energency reserve and allocation provisions of the International Energy Agreement.

12/ See chap. IV, sect. C, and chap. V, sect. C, 11 and 12.

13/ Système International d"Unités.

14/ Following the terminology recommended earlier, they should be designated as "primary energy input".

15/ "Final energy users" include industry, distribution and other services (all of which are "intermediate consumers" in the national accounts sense) as well as "domestic users" and other "final consumers" in the national accounts sense. Autogeneration of electricity by industry and the production of blast furnace gas might be regarded as part of the energy industries' activities, or as one among other uses of energy supplied to final users. This point is considered further in later chapters.

16/ SOEC (Luxembourg) has published overall "Useful Energy Balances", ending with "final energy use", shown on both an energy supplied and useful energy basis for 1975, 1978 and 1980.

17/ See, for example, Slesser (1978).

18/ See annex II for a fuller account of the nature of nuclear power.

19/ See La Revue de l'Energie (January 1976).

20/ See Ramain (1977).

21/ Waste heat emission does not only occur at power stations. Ultimately all energy used returns to the environment as heat: see Nebbia (1975) who would like to see all losses to the environment accounted for.

22/ This is the usual situation in developed countries. By contrast, India has for 10 years or more based its energy statistics on an accounting unit (the coal replacement ton) that reflects the useful energy obtainable in current practice from each energy source. See Chatterjee (1971).

23/ See P. Ramain "Equivalences entre électricité et combustibles - éléments pour une discussion critique", Revue de l'Energie, 1976. M. Ramain develops his argument further in his book (1977).

24/ There are at least 3 different levels of measurement of electricity production: generation less used in power stations = available (or sent out) less used in pumped storage = net sent out.

25/ See OECD (1977).

26/ Once set in operation, the heat release from a reactor cannot be shut down completely and then re-started with the flexibility of a fossil fuel station. Consequently nuclear stations are used as continuous, or "base load" stations.

27/ This useful general designation is used by Guyol (1977).

28/ Austria, Canada, Iceland, Norway, Portugal, Spain, Sweden, Switzerland, New Zealand, Turkey, and the United States of America are classified as "hydro countries" by OECD.

29/ "Primary energy input" or "fossil fuel equivalent" can include secondary energy sources (e.g. fuel oil) used by the transformation industries.

30/ Mention has already been made of the IEA convention of imputing to each and every petroleum product the average rate of refinery fuel use and refinery loss. All products are multiplied by 1.065 to give crude oil equivalent.

31/ See Nebbia (1975) and Longva (1977).

32/ IFIAS (1974) recommends such an approach. Only GCV can be assessed directly.

33/ See also foot-note 21/.

34/ It can also be argued that GCV is the only proper basis for evaluating the energy content of feedstock to petrochemical processes that do not result in the production of water vapour with a consequent loss of latent heat of condensation in exhaust gases.

35/ For a fuller discussion of this problem see Laading (1960) and Ramain (1977).

36/ SOEC (1976) ceased using the TCE as from 1978 (see paragraph 151). 1 Gcal = 10^6 kcal = 4.19 gigajoule (GJ) so that 7 Gcal = 29.3 GJ.

37/ Statistical Office of the United Nations (1977).

38/ United Kingdom (1977).

39/ The United Kingdom describes its TCE figures as showing "tons of coal or coal equivalent".

40/ See Chatterjee (1971).

41/ These cover 20 national official balances (Argentina, Austria, Brazil, Canada, Finland, France, Federal Republic of Germany, Hungary, India, Italy, Japan, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Sweden, the United Kingdom and the United States of America); five balances produced by national economic research institutes in Austria (Oesterreichisches Institut fuer Wirtschaft (OIW)), France (Centre d'Etudes Regionales sur l'Economie de l'Energie (CEREN) (Paris) and Institut Economique et Juridique de l'Energie (IEJE)), Italy (Bari) and Japan (Institute of Energy Economics (IEE)); five balances produced by international organizations, the United Nations (New York), ECE (Geneva), OECD (Paris), EEC (Brussels) and SOEC (Luxembourg); one produced jointly by two institutes engaged in international analysis (Brookhaven National Laboratory, United States, and Kern-Forschungs Anlage (KFA) Julich, Federal Republic of Germany; two used by international bodies, the Workshop on Alternative Energy Strategies (WAES) and the World Energy Conference (WEC); and four used by major international oil companies. In the Federal Republic of Germany the balance is published by the Energy Balance Working Party which comprises representatives from Government, the universities and the energy industries. Except where otherwise stated, references to SOEC balances relate to those published before 1978.

42/ See para. 29.

43/ As has been pointed out already, no energy is lost in the strictly thermodynamic sense, but all energy released from its thermodynamic source by nature or by man moves down the temperature scale until the remaining heat is at too low a temperature to be put to any use of value to man.

44/ In the basic matrices in original units, columns are used for energy sources.

45/ The Institute of Energy Economics (IEE), Tokyo, has also published balances for Japan in the more common top down form.

46/ This refers to the new format proposed by the Federal Energy Agency (FEA), United States, not to the balance published by the Bureau of Mines. The latter is covered in the following section.

47/ Japan is the only country examined that produces balances only on a financial year basis.

48/ Ministry of Industry and Commerce (MIC).

49/ Ente Nazionale Idrocarburi (ENI).

50/ This treatment is particularly appropriate for major energy exporting countries, in their national energy balances.

51/ The "make" matrix shows the quantities of each energy commodity that are made by each producing industry, imported or coming from stock. The "absorption" matrix shows the quantities of each commodity delivered to each inland user, to exports or to stocks.

52/ Annual Bulletin of Energy Statistics.

53/ See also IFIAS recommendations (already cited) and UNIPEDE (1976).

54/ Austria (OIW), Federal Republic of Germany, Netherlands (since 1977), Sweden, the United States (FEA), Brookhaven/Julich and SOEC.

55/ Published by the French National Committee for the World Energy Conference.

56/ Argentina used to publish a detailed overall energy balance but for the past 10 years or so has published separate tables showing, respectively, primary and secondary energy supplies, transformation inputs and outputs, and final users. Brazil publishes a relatively simple overall energy balance but this only shows quantities on a primary energy input basis.

57/ Hasty reference to the "Export" row might mislead a reader into interpreting a negative figure as meaning a net import.

58/ Chap. III, sect. C.

59/ Some balances claim to record the heat released by reactors but in practice all seem either to estimate this quantity from generation efficiencies or to assume a percentage efficiency in order to arrive at an opportunity cost of nuclear electricity in terms of fossil fuels.

60/ Used rather than 85%, for simplicity.

61/ For detailed accounts of some forecasting methods see for example Proceedings of the IEA/OECD Workshop on Energy Data of Developing Countries, vol. I (Paris 1978); also, United Kingdom of Great Britain and Northern Ireland, Department of Energy, "Energy forecasting methodology" (1979).

62/ Heat pumps fit in very simply. They have negative inputs of electricity and of environmental heat (in the "Total" column), and a positive output in the "Heat" column.

63/ For the full titles of these and other classifications cited, see annex IV.

64/ "Bulletin of Energy Statistics", No. 3/1976, supplement.

65/ See Roberts and Hawkins (1977). More detailed figures are given for each stage of use from extraction through transformation to final energy use in United Nations/ECE (1976). That report also discusses in more detail the problem of assessing energy efficiencies. See also Laading (1960), Guyol (1971) and Ramain (1977).

66/ See for example, United Kingdom, Department of Energy, "Energy forecasting methodology" Energy paper 29 (London, 1978).

67/ See also the detailed analysis made by the ERG (Cambridge, England) for the WEC (1977).

68/ See also CBI (1975) and Chesshire and Buckley (1976).

69/ Laading (1960) recommended that efforts should be made to produce a value balance sheet, as well as an energy balance sheet, and illustrated the proposal with tables for the OECD area. (SOEC has sponsored work along these lines in its member countries.)

70/ See Proceedings of the International Conference on Peaceful Uses of Atomic Energy, Geneva, 8-20 August 1955 (United Nations publication, Sales No. 56.IX.1).

71/ Longva (1977).

Annex I

COMBINED HEAT AND POWER AND MEASUREMENT PROBLEMS

A. General

1. Combined heat and power (CHP) production can take one of two forms. The first consists in recovering the maximum amount of exhaust heat from the steam turbines in public supply electricity power stations. The second consists of using for electricity generation a part of the heat produced in industry as steam primarily for process and space heating. In both cases, the overall efficiency of fuel use is greater than if the same amount of heat and electricity is produced in separate heat-only and electricity-only schemes (but cost and other considerations often make separate production plants more economic than CHP).

2. The maximum amount of energy that can be derived from a given quantity of steam is only about 35% in the case of transformation from heat into mechanical work. This is a consequence of the Second Law of Thermodynamics. The amount of work that can be extracted from a given amount of heat depends on the reduction that can be brought about in the temperature of that reservoir of heat, a/ and with current boilers, turbines, piping and insulating materials, it is not possible to produce a greater percentage temperature difference between the steam input and output than about 40%. Small friction and other losses in the turbo-generator set reduce this to about 35%.

B. Public supply power stations

3. The large amount of exhaust heat representing 65% of the heat in the steam input is the energy overhead, or direct energy cost, of the process of upgrading simple heat to highly adaptable electricity. The temperature of the exhaust heat is, however, too low for economic transmission to other users who are generally remote from large public supply power stations, and most of the condensate is therefore cooled to become tepid water before being discharged into rivers, lakes or the sea.

4. It is clearly desirable to recover at least some of the exhaust heat from public supply power stations, and in some countries this has been done for many years. Other countries have been studying the scope for such heat recovery through the siting of new power stations and new residential or commercial areas nearer to each other. Such heat recovery would not generally require any reduction of the amount of electricity produced from any given amount of fuel consumed.

C. Industrial CHP

5. In the case of heat-only plants in industry, the efficiency of the system is of the order of 90% since the losses in the boiler house are only about 10%, and so almost the whole of the heat released from the fuels consumed is available as steam for process and/or space heating. If the electricity requirements of an industry (or of a given plant) are at present bought in from the public supply system, it may be economic for that industry or plant to use a part of the heat output from its boilers to drive one or more steam turbo-generators. Such a switch from the public electricity supply to auto-generation will necessitate an increase in the

temperature and pressure of the steam output from the boilers in order to provide the energy needed to drive the turbine and its generator in addition to providing the energy required in the process/space heat steam supply.

6. In this case, the exhaust steam from the turbine is available for use and can be regarded as a joint product with electricity or as a by-product of generation whose energy value can be offset against the total energy input to the turbine. On either basis (i.e. treating the exhaust heat as a joint product or as a by-product), the energy input to generation can be defined as the difference between the heat in the steam input to, and the heat in the exhaust from the turbine. Since the electro-mechanical efficiency of a turbo-alternator is about 95%, the overall efficiency of electricity generation by CHP may be said to be about 85%.

7. Measured in relation to the heat input to the turbine, the efficiency of generation will be very much less even than the 35% or so typical of public supply power stations, since only a very small fraction of the heat in the steam input needs to be extracted by the turbine in order to generate the relatively small amount of electricity required by a particular industrial establishment.

D. Treatment in an energy balance

8. Irrespective of whether the net energy input is used in place of the gross energy input as the basis for defining the energy use by CHP electricity, the effect of distinguishing CHP electricity in an energy balance is that the time-trend of total electricity generation will differ from the time-trend of the primary energy input to electricity if the proportion of CHP electricity in total electricity changes through time. It is this inconvenient effect in the case of hydro and thermal electricity that has led the proponents of the "partial substitution" approach to advocate imputing to hydroelectricity a notional fossil fuel input using an assumed generation efficiency of about 33%.

9. Such a treatment in the case of CHP would seem very artificial and a gross oversimplication of the interrelationship between the demands for heat and for electricity. This consideration reinforces the recommendation in chapter III that industrial CHP should be treated as one differentiated form of use of energy supplied to industry.

10. In chapter V, section C, 4, the different practices of different countries were noted and the Swedish treatment was commended, in which the inputs to CHP together with the two outputs electricity and heat are all recorded in a single row. The same chapter noted that for some purposes (e.g. energy analysis) allocation of the inputs between the two outputs is nevertheless considered necessary. In chapter VI, section C, 2, a framework was proposed in which the flows of purchased, transformed and recovered energy within an industrial user could be analysed in some detail.

E. Allocation methods

11. If it is judged necessary to record on separate rows the electricity and heat outputs from CHP, each with its allocated share of the total fuel input, there are a number of possible methods of allocating inputs between the two outputs:

(a) Compare two systems, one of which provides heat only and another that would provide that same quantity of heat together with electricity, and then define the difference in total energy input as being wholly attributable to the electricity. (This is the basis used in industry when considering the fuelling implications of adopting CHP in place of a heat-only plant.);

(b) Compare the total energy input to a CHP scheme with the total quantity of heat recovered from the turbine, after "grossing up" the latter quantity of heat by the reciprocal of the boiler efficiency, and then define the difference between these two heat quantities as the input to electricity generation. (This is the basis recommended by UNIPEDE.);

(c) Record the quantity of heat in the steam input to and in the recovered heat output from the turbine, and then define this difference as the energy input to the electricity. (This basis is almost the same as (b) but it ignores boiler losses. This basis is being introduced in the Netherlands.);

(d) Allocate the total energy input between heat and electricity in proportion to the ratio of the energy content of the heat and electricity output. (This is the basis recommended by IFIAS.)

The four bases are all essentially the same in effect, as is shown in the note at the end of this annex.

12. If the framework suggested in recommendation 28 is used to show the allocated inputs to electricity and to heat, the figures might look like this:

	Fossil fuel	Electricity	Heat		Net total
			Initial	Recovered	
Generation	-10	+8	-	-	-2
Heat production	-90	-	+77	-	-13
Sum	-100	+8	+77	-	-15

13. If the same framework is used to show the interdependence between the two activities, then the figures would look like this:

	Fossil fuel	Electricity	Heat		Net total
			Initial	Recovered	
Generation	-100	+8	-	+77	-15
Heat production	-	-	+77	-77	-
Sum	-100	+8	+77	-	-15

14. Further discussion of the usefulness of these alternative treatments is desirable. The two diagrams illustrate in their simplest form a heat-only system consisting of a boiler with a fuel input and a steam output, and a CHP system with a boiler and a back-pressure turbine driving a generator. In practice more complex CHP configurations may be used with steam take-off points between the input and exhaust points on the turbine and with two or more turbines with different characteristics, to give flexibility in the amounts and proportions of electricity and heat output.

See Corr. I

<u>Notation:</u>

F_h = Fuel input to boiler for heat-only output

F = Fuel input to boiler for CHP output

F_e = Fuel input to electricity

E_b = Boiler efficiency

I = Heat input to turbine

E_t = Turbine efficiency

Corr. 1

E_g = Generator efficiency

H = Heat output

E = Electricity output

<u>Estimate (i)</u>:

$$F_e = F - F_h \qquad \text{(i)}$$

<u>Estimate (ii)</u>:

$$F_e = F - \frac{H}{E_b} \qquad \text{(ii)}$$

<u>Estimate (iii)</u>:

$$F_e = I - H = (E_b \cdot F) - (E_b \cdot F_h) = E_b\,(F - F_h) \qquad \text{(iii)}$$

<u>Estimate (iv)</u>:

$$F_e = \left(\frac{E}{E + H}\right) \cdot F = \frac{(I-H)\ E_g}{(I-H)\ E_g + H} \cdot F$$

Let us assume that $(1 - E_g)$ is very small compared with errors in other data when aggregated for a country, so that we can put E_g approximating 1

Then

$$F_e = \left(\frac{I - H}{I}\right) \cdot F = \frac{(E_o \cdot F) - (E_b \cdot F_h)}{E_b \cdot F} \cdot F = F - F_h \qquad \text{(iv)}$$

Notes

a/ Theoretically the efficiency of a heat engine $E = 1 - (T2/T1)$ where T1 is the input temperature and T2 is the output temperature of the heat used to make the engine run. Both temperatures are measured in degrees Kelvin. 0°C = 273°K. The maximum technically attainable temperature for steam is about 600°C = 873°K and the lowest readily attainable temperature in a turbine is about 30°C = 303°K. From this it follows that:

$$E = 1 - (303/873) = 0.653 \text{ or about } 65\%$$

In practice only about half this theoretical level is attained. For a fuller exposition of the physical relationships see for example "Fundamental concepts in technology: energy", Open University (1975).

Annex II

THE NUCLEAR FUEL CYCLE*

Conventional and nuclear electricity

The principles employed in generating electricity in a nuclear power station are essentially the same as those employed in a conventional, fossil (coal, oil or gas) fired station. In both types, energy in the form of heat is released from a fuel at a controlled rate. This heat is used to boil water kept under pressure, so producing high-pressure steam.

Chemical reaction provides the source of energy for fossil fired power stations. Essentially they involve a reaction between the oxygen atoms of the air with the carbon or hydrogen atoms (or their compounds) present in coal, oil or gas. The rate of reaction, and thus the rate of energy released, is determined by controlling the rate at which fuel or air is supplied. A totally different kind of reaction takes place in a nuclear reactor involving the breaking up, or fissioning, of the nuclei of atoms.

The atom

Although atoms are indescribably small, they are made up of still smaller entities. Each atom contains a central core, or nucleus, which carries a positive electrical charge. The atom also contains very much lighter particles - electrons - which each carry a negative charge. These electrons move around the nucleus in orbits at various, and relatively immense, distances (ten thousand times the diameter of the nucleus).

The nucleus itself consists of two types of fundamental particle: protons and neutrons. Each proton has a positive charge which is equal but opposite to that of the electron (which orbits around the nucleus), and the neutrons have no charge. For any particular atom the number of orbital electrons exactly equals the number of protons so that the net electrical charge of the atom is zero. The complete nucleus of protons and neutrons is bound together by immensely strong forces - the so-called nuclear forces - which counteract the electrostatic forces of repulsion acting between the protons.

Nuclear energy

Some naturally occurring nuclei are unstable - the nuclear forces only just balance the electrostatic forces. In this state the nuclei can spontaneously break up, hurling fragments out at great speed. Although such radioactive decay occurs in nature, the rate at which energy is released in naturally occurring radioactive materials is too low for use to be made of this phenomenon as a source of energy.

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* This text is a shortened and slightly rearranged version of the very clear description of the nuclear fuel cycle given in United Kingdom, Department of Energy, "Nuclear energy in the United Kingdom - power from the nucleus", Information Directorate fact sheet No. 6 (1977).

However, some elements have the property that their nuclei may be induced to fission if energy is supplied to them. This can be effected by bombarding the nuclei and one of the most effective ways is to bombard the nuclei with neutrons. They are particularly effective since they have no electric charge and can approach the nucleus without being repelled by the electrostatic forces.

In principle, by supplying sufficient energy in this way, nuclei of all the elements can be broken up, but in most cases the amount of energy needed to do so is greater than that released. There is, in fact, only one naturally occurring substance which has the property of yielding a net gain in energy when fissioned, and at the same time releases further neutrons which can be harnessed to induce fission in other nuclei; this is the isotope a/ of uranium, known as U235. Such material is called "fissile".

Uranium and fission

Natural uranium consists of a mixture of two isotopes - about 0.7% of the fissile uranium 235, and about 99.3% of uranium 238, which is not readily fissile. The concentration of uranium 235 can be increased, using certain techniques based on the difference in physical properties of the isotopes. Such uranium is said to be "enriched". Although only this one fissile material occurs in nature, two other fissile materials can be synthesized from naturally occurring substances. These are plutonium 239 (from uranium 238) and uranium 233 (from thorium 232).

A crucial feature of the fissioning of uranium 233, uranium 235 or of plutonium 239 is that, as well as energy, neutrons are liberated - between two and three neutrons per fission - in the process. These neutrons can, under certain circumstances, go on to induce further fission reactions in other fissile nuclei which will in turn lead to more neutrons and more fission reactions. They produce in fact a self-sustaining nuclear reaction analogous to the chemical chain reaction of combustion.

If each fission, on average, induces more than one subsequent fission the number of reactions in successive time intervals would increase. On the other hand if each fission induces on average less than one further fission, the rate of reaction would decline and eventually peter out. A nuclear reactor is a device in which the chain reaction can be made to proceed at a steady rate, that is to say it can be controlled in such a way that, on average, one fission induces only one further fission. Although billions of fissions may take place every second, the total number occurring each second remains constant. This number - the fission rate - determines the rate of energy release in the reactor.

Nuclear reactors

The essential requisites of a nuclear reactor are:

(a) An assembly of material containing an adequate number of fissile nuclei - the fuel;

(b) In most cases, a "moderator" to slow down the initial speed with which neutrons are ejected at fission;

(c) A system for controlling the fission rate;

(d) A coolant to remove the heat generated in the fuel and to transmit at least a large part of that heat to water in order to convert it into steam.

Natural uranium (which consists of 1 atom of the fissile uranium 235 for about every 140 atoms of uranium 238 which are not fissile) will not, in its natural state, produce a sustained chain reaction. This is because the neutrons released in the fission of uranium 235 are travelling at high velocities and are more likely to be captured (absorbed) by the very much more abundant uranium 238 nuclei than go on to produce further fission.

One way of getting nearer a sustained chain reaction is to use fuel in which the concentration of uranium 235 nuclei has been increased b/ so that the probability of a neutron striking a fissile atom and causing a subsequent fission is also increased. Another way makes use of the fact that low speed neutrons are more likely - by a factor of up to 200 - to produce fission in uranium 235 than be absorbed by the more abundant uranium 238. This can be arranged by associating the fuel (natural or slightly enriched uranium) with a moderator. This is a material comprised of nucleus of the light elements - hydrogen or its isotope deuterium (in water or heavy water) or carbon (in graphite). Neutrons passing through such material will lose energy in colliding with the light nuclei and will not be appreciably absorbed by them. The slowed down neutrons are called "thermal" neutrons and this is the name given to all reactors that use moderators.

The heat produced in the fission process must be transferred from the reactor core if it is to be used. This is done by passing a coolant over the fuel elements. After passing through the reactor, such a coolant may be pumped in a closed circuit through a heat exchanger, where it gives up the heat it is carrying to boil water under pressure, and then back to the reactor again. In some reactors, where water is used as a coolant, it is allowed to boil and the steam produced is fed directly to a turbine before being condensed and returned.

The fuel for thermal reactors may be natural uranium or enriched uranium, or uranium to which plutonium 239 has been added. A single fuel element usually consists of a number of tubes, or cans containing the fuel, and there are many of these fuel elements arranged in the core of a reactor, all surrounded by the moderator. Unlike a fossil fired power station, where vast quantities of fuel, coal or oil, are continuously fed into the combustion chamber, the fuel in a nuclear reactor is loaded into the core and remains there for several years, and the average annual throughput is small.

Conversion and breeding

In a reactor, neutrons generated in fission may be either absorbed by other fissile material and so produce further fissions, or be absorbed by other materials. The latter process can be used to generate new fissile material which can be used to fuel a reactor. For example, uranium 238 which is not itself fissile, may be converted, through the absorption of a neutron, to plutonium 239 which is fissile. Similarly, thorium 232 may be converted to another fissile species of uranium, uranium 233 (but at present this alternative route to producing fissile material has not been pursued extensively). Materials which can be converted in this way are said to be "fertile".

Conversion of fertile material to fissile material takes place in all nuclear reactors to a greater or lesser extent. But clearly, if the conversion process could be made sufficiently large then it might be possible to produce more fissile material (from the fertile material) than is consumed. In such a situation, the stock of fissile material would grow. Such a device is called a "breeder reactor".

Fast reactors

Fast reactors do not employ a moderator to slow down the speed of neutrons. Instead (and in order to increase the chance of fast neutrons being absorbed by fissile nuclei and causing subsequent fissions), they rely simply upon a high concentration of fissile material in order to sustain a chain reaction. In the case where the fast reactor fuel is plutonium 239, a significant number of spare neutrons are available, and these can be used to generate fresh plutonium from uranium 238. It can convert uranium 238 into plutonium more rapidly than it burns plutonium to generate energy - so that the initial stock of plutonium grows, or "breeds". This new fuel can be used for re-fuelling the reactor, or for fuelling thermal reactors, or for fuelling further fast reactors.

Fuel reprocessing

Nuclear fuel may be in a reactor for several years. Yet even after this time by no means all of its fissile atoms will have been used. It is however necessary to remove the fuel elements, although only partially used, for two reasons. First, the fission fragments formed in the elements absorb neutrons and tend to kill the chain reaction, and secondly, the elements can become physically distorted following prolonged exposure to nuclear radiation.

The spent (irradiated) fuel may be valuable because of its remaining uranium 235 content and additionally because some of the uranium 238 will have been converted to plutonium. The irradiated fuel may therefore be reprocessed in order to separate out the fissile material and the radioactive fission fragments - the former for use as new fuel and the latter for safe storage.

Notes

a/ In nature nuclei frequently occur with the same number of protons but different numbers of neutrons. These are said to be different isotopes of the same element.

b/ i.e., "enriched" uranium.

Annex III

NUCLEAR ACCOUNTING

1. The distinguishing characteristics of nuclear energy compared with conventional thermal generation of electricity may be summarized as follows:

(a) Although nuclear energy is now almost always converted into electricity before being used as a source of heat or work, nuclear heat may be used directly for industrial purposes in the future: electricity measurement will not on its own be sufficient in future energy balances;

(b) Even though conversion to electricity is usual now, countries that generate nuclear electricity import nuclear fuels (in unfabricated or fabricated form), may export such fuels after fabrication into fuel elements for reactors, and may also import or export irradiated fuels for reprocessing: foreign trade occurs in nuclear fuels, whether or not such countries also import or export electricity;

(c) Only a very small fraction of the heat that is theoretically obtainable from a given quantity of nuclear fuel in a reactor is actually obtained within one year: the difference between fuel input and electricity output does not represent just the transformation loss but also covers a large amount of heat that may be "accessed" in more than one subsequent year;

The quantity of heat released by a reactor in a year, and the amount of heat that is recoverable from a given quantity of irradiated fuel, both depend on the current and future types of reactor used and on the current and future technology of fuel reprocessing.

2. It is therefore clear that an energy balance should, in principle, be able to account for nuclear fuels as such and not merely for the electricity into which those fuels are converted. In practice, there may be security or other reasons why complete stock-and-flow accounting cannot be implemented at present in published balances, but this need not prevent consideration of the ability of the energy balance structure recommended in this report to accommodate the full range of transactions in nuclear fuels.

Treatment in a balance

3. The peculiarities of nuclear energy can be catered for very simply in the recommended matrix balance format. All that are needed are additional rows for the new activities fuel enrichment, fabrication of fuel elements, and reprocessing of irradiated fuels, and additional columns for the new commodities - natural, enriched and depleted uranium, plutonium and irradiated fuel. If and when fast breeder reactors are in operation to a significant degree, it may be useful to separate fabrication and reprocessing into that associated with thermal reactors and that associated with breeder reactors.

4. The existing rows for imports and exports can be used for foreign trade in any given state (natural, enriched etc.) of nuclear fuel, but the stock change row would need to be split to distinguish stock changes at fabrication plants,

enrichment plants and in reactor cores. This last category would be particularly important during the years when nuclear stations are being built.

5. Diagram 1, below illustrates the relevant rows and columns of an expanded energy balance. Arrows have been added to show the nature and direction of the various possible flows. The flows for thermal and for fast reactors are shown separately.

Measurement

6. There remains the problem of how to quantify in a common accounting unit the various states of nuclear fuels. (An initial balance in original units (tons) should present no great difficulty.) The problems arise when expressing in a suitable multiple of the joule - probably the petajoule (PJ) - the tonnages of natural, enriched, depleted and irradiated fuel.

7. There are two possible solutions to this problem. Firstly, the assumption may be made that because every atom in a ton of fissile material is theoretically capable of being split, the energy content of one ton of uranium is 82 PJ (and correspondingly for 1 ton of plutonium or other fissile material according to its atomic weight). On this basis, the energy content of the stock of fuel in a reactor core is a very large number of PJ, and the energy content of the irradiated fuel at the end of a year is similarly a very large number, and by comparison the amount of energy released as heat during the year will be a very small number.

8. The second solution would be to impute to each ton of natural uranium the energy value of the heat that could be extracted from it during a year of use in the most common type of reactor (light water). Diagram 2, made available by the International Atomic Energy Agency, illustrates the relationship between physical quantities of natural and enriched uranium and the corresponding quantities of energy accessed as heat and converted into electricity. On this basis the energy value per ton would be only about 0.3-0.4 PJ.

9. There would remain the problem of what energy value to attribute to the irradiated fuel (and to the depleted uranium resulting from the enrichment process). Once more, there are two possible bases. The first is to assume that every atom is fissile at some unknown future date. The second is to assess the amount of heat capable of being extracted with currently known technologies from the material in question. The table that follows diagram II shows how the energy obtainable from a given quantity of uranium varies by a factor of up to 2.5 with different types of thermal reactor, and by a factor of up to nearly 130 with breeder reactors.

10. If it is thought realistic to produce an expanded energy balance showing fissile materials in their various states, then closer consideration will need to be given to the energy values to be attributed to plutonium and irradiated fuels. Even if this stage of elaboration cannot yet be reached, it is important to note that the matrix balance structure is robust enough to accommodate greater detail on nuclear materials if and when the raw statistical data is available and conversion factors agreed upon.

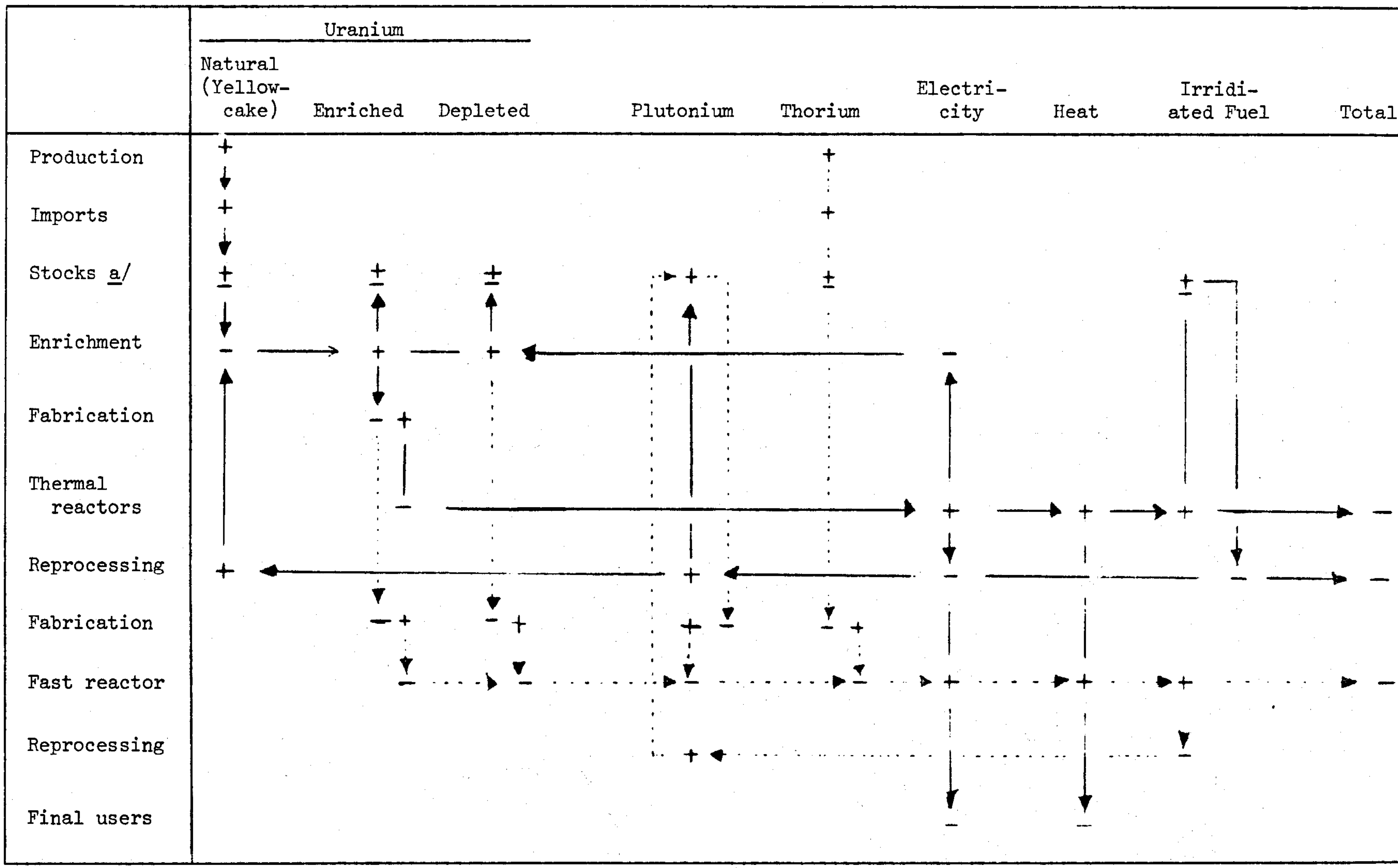
11. Even though a full elaboration of the balance may not yet be possible, supplementary tables should show foreign trade, at least in original units, in nuclear materials. Three possible bases for expressing such trade in joules would be:

(a) Value each ton as if each and every fissile atom could be fissioned at some time;

(b) Value each ton in terms of the average annual amount of heat that can, with current reactor and reprocessing technology, be extracted;

(c) Enter for the year of import and (as imports) in each subsequent year of the commercial life of that quantity, the value assessed as in (b), above.

Diagram 1. Energy balance accounting framework and treatment of nuclear cycles

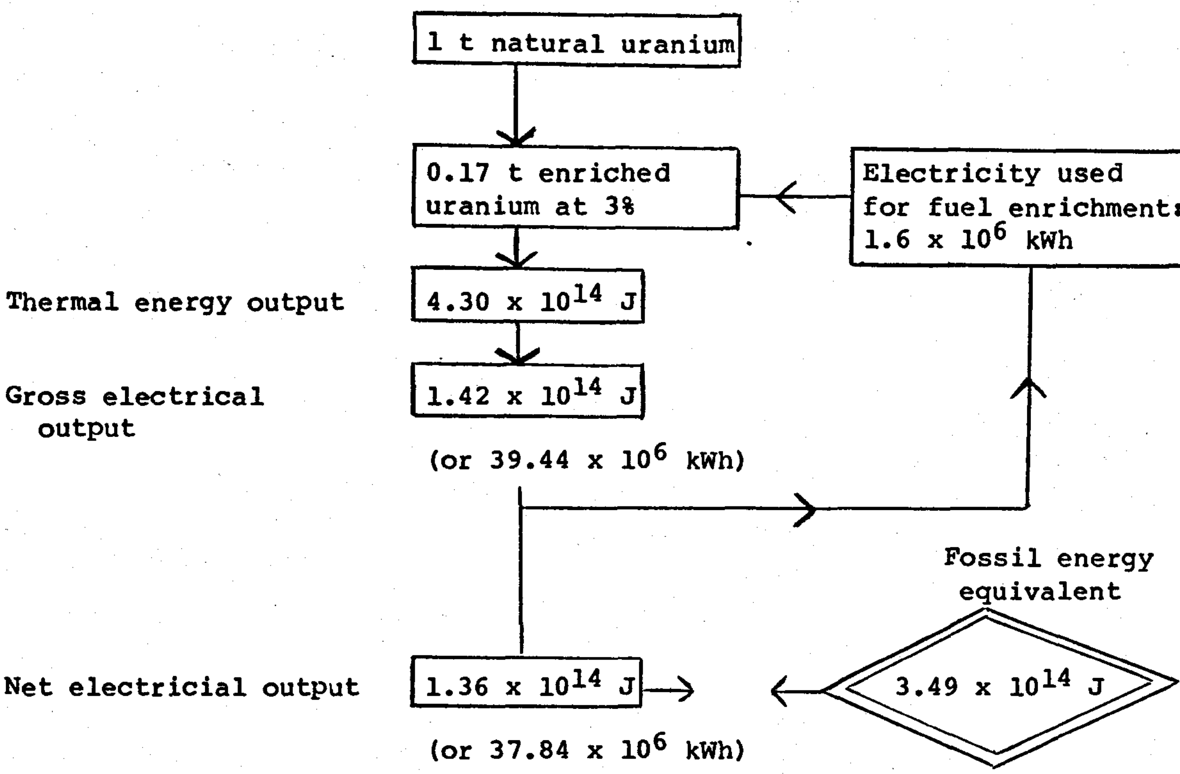


a/ To be subdivided between (a) fabrication plants; (b) enrichment plants; (c) reactors; and (d) other.

Diagram 2: Energy Equivalent to one ton of natural uranium

Basic hypothesis. Since most nuclear reactors are at present used to supply electricity, the energy equivalent of one ton of natural uranium is estimated on the basis of the energy content of fossil fuel needed to supply the same amount of electricity.

Flow-chart of reference case. This graph indicates how much net energy could be supplied by using one ton of natural uranium and a light water reactor. As this type of reactor is the one most used at present, it can be taken as the reference case.



Reference case: Uranium used in a light water reactor without recycling uranium and plutonium.

1 t natural uranium = 3.5×10^{14} J

Alternatively, one ton of enriched uranium at 3% could be taken as equivalent to 2.1×10^{15} J.

<u>Other cases of uranium use</u>. If the uranium and plutonium are recycled in the light water reactor, or if other reactor types are considered, the energy equivalent of 1 ton of natural uranium in the reference case should be multiplied by the following factors:

	Types of reactor and fuel cycles	Factor of multiplication
1.	<u>Light water reactor</u> (LWR)	
	Without U and Pu recycle	1.0 (reference)
	With U recycle but not Pu	1.2
	With U and Pu recycle	1.5
2.	<u>Heavy water reactor</u> (HWR)	
	Without any recycling	1.2
	With Pu recycle	2.5
3.	<u>High temperature gas cooled reactor</u> (HTGR) ...	
	U-Th cycle with U recycle	2.1
4.	<u>Fast breeder reactor</u> (FBR)	
	With an infinite series of U and Pu recycles the FBR burns 60% of natural uranium while the LWR burns only 0.7%.	129.0

Annex IV

MAIN INTERNATIONAL CLASSIFICATIONS

United Nations

BEC	Broad Economic Categories classification
ICGS	International Standard Classification of All Goods and Services
ISIC	International Standard Industrial Classification of All Economic Activities
SITC	Standard International Trade Classification
SNA	System of National Accounts

Customs Co-operation Council, Brussels

CCCN (BTN)	Customs Co-operation Council Nomenclature (Brussels Tariff Nomenclature): for the classification of goods in custom tariffs
HS	Harmonized System, now under development by the Customs Co-operation Council

European Communities

NACE	Nomenclature général des activités économiques dans les Communautés européennes (General Industrial Classification of Economic Activities within the European Communities)
NIMEXE	Nomenclature of goods for external trade statistics of the community and for statistics of trade between member States,
NIPRO	Common Nomenclature of Industrial Products

Other

CSTE	Commodity Classifications for Transport Statistics in Europe
GCP	General classification of industrial and agricultural products of the member countries of the Council of Mutual Economic Assistance (CMEA), Moscow

Annex V

ENERGY IN NACE/NIPRO

1. Energy and water

Classes	Groups	Subgroups and items	NACE-ref	NIPRO-code	Description	Unit of measurement
11					Extraction and briquetting of solid fuels	
	111				Extraction of hard coal and manufacture of patent fuel	
		111.1			Extraction of hard coal (including open cast)	
			111.10		Coal	
			111.10	1	Coal, not briquetted or agglomerated	
				10	Coal, not briquetted or agglomerated	
				101	Coal (e.g. anthracite, lean, forge, fat, gas and long coal) in pieces, nuts, fine or dust coal, medium-sized coal or slurries	t
				105	Methane	m^3+kcal
		111.2			Manufacture of patent fuel (including smokeless and similar solid fuels manufactured from coal)	
			111.20		Coal briquettes	
			111.20	1	Coal briquettes and other coal agglomerates	
				10	Coal briquettes and other coal agglomerates	

Classes	Groups	Subgroups and items	NACE-ref	NIPRO-code	Description	Unit of measurement
				100	Coal briquettes and other similar solid fuel produce from coal, in the form of egg-shaped or other briquetted products	t
	112				Extraction and briquetting of lignite	
		112.1			Extraction of black lignite	
			112.10		Pitch coal	
			112.10	1	Pitch coal	
				10	Pitch coal	
				100	Pitch coal, also pulverized or dehydrated and/or dried	kg
		112.2			Extraction of brown coal	
			112.20		Raw lignite (without pitch coal)	
			112.20	1	Raw lignite, not briquetted or agglomerated	
				10	Raw lignite, not briquetted or agglomerated	
				100	Raw lignite, also dehydrated and/or dried (without jet)	kg
		112.3			Manufacture of brown coal briquettes	
			112.30		Lignite briquettes	
			112.30	1	Lignite briquettes and other lignite agglomerates	
				10	Lignite briquettes and other lignite agglomerates	

Classes	Groups	Subgroups and items	NACE-ref	NIPRO-code	Description	Unit of measurement
				100	Lignite briquettes and other lignite agglomerates	kg
12	120				Coke ovens	
		120.1			Colliery coke ovens	
			120.10		Mine coke and coke-oven gas	
			120.10	1	Mine coke and coke-oven gas	
				10	Mine coke and coke-oven gas	
				101	Mine coke	t
					Mine coke-oven gas	m^3+kcal
		120.2			Iron and steel industry coke oven	
			120.20		Metallurgical coke and coke-oven gas	
			120.20	1	Metallurgical coke and coke-oven gas	
				10	Metallurgical coke and coke-oven gas	
				101	Metallurgical coke	t
					Metallurgical coke-oven gas	m^3+kcal
		120.3			Manufacture of brown coal briquettes	
			120.30		Other coke-oven coke and gas (from independent coke-ovens)	

Classes	Groups	Subgroups and items	NACE-ref	NIPRO-code	Description	Unit of measurement
			120.30	1	Other coke-oven coke and gas as well as low-temperature coke from coal and lignite (from independent coke-ovens) (excluding coke from coal tar pitch and petroleum coke)	
				11	Other coke-oven coke (including low-temperature coke) from coal (from independent coke-ovens)	
				110	Other coke-oven coke (including low-temperature coke) from coal (from independent coke-ovens)	t
				12	Other coke-oven gas (from independent coke-ovens)	
				120	Other coke-oven gas (from independent coke-ovens)	m^3+kcal
				13	Coke from coal for the production of electrodes	
				130	Coke from coal for the production of electrodes (pure and very pure coke with an ash content of 2% max.)	t
				15	Coke and low-temperature coke from lignite	
				150	Coke and low-temperature coke from lignite	t
				17	By-products from coking and lignite	
				171	Retort carbon (retort graphite) in pieces or ground	kg
				173	Crude tar from coking or low-temperature coking of coal and lignite including dehydrated	t

Classes	Groups	Subgroups and items	NACE-ref	NIPRO-code	Description	Unit of measurement
				174	Crude recovered sulphur, by-product of coke-ovens	t
				175	Crude benzene	t
				177	Ammonium sulphate	t
				179	Other by-products from the coking of coal and lignite (e.g. ammoniacal liquid from cleaning spent gas)	t
13					<u>Extraction of petroleum and natural gas</u>	
	131				Extraction of petroleum	
		131.0			Crude oil (including topped crude and associated natural gas)	
			131.00		Crude oil (including topped crude and associated gas)	
			131.00	1	Oils, crude and topped crude from petroleum or bituminous minerals and associated natural gas	
				11	Crude petroleum (including topped crude)	
				110	Crude petroleum (including clarified, dehydrated, stabilized, demulsified, desalted and similarly slightly treated so that the essential character of the crude oil is retained)	t
				13	Crude oil from bituminous minerals	
				130	Crude oil from bituminous minerals	t

Classes	Groups	Subgroups and items	NACE-ref	NIPRO-code	Description	Unit of measurement
				15	Associated natural gas	
				150	Associated natural gas	m^3+kcal
	132				Extraction and purifying of natural gas	
		132.0			Natural gas (non associated) and natural gas liquids	
			132.00		Natural gas (non associated) and natural gas liquids	
			132.00	1	Natural gas (non associated)	
				10	Natural gas (non associated)	
				101	Crude natural gas (not purified)	m^3+kcal
				104	Natural gas, desulphurized or otherwise purified, in the gaseous state	m^3+kcal
				107	Natural gas, desulphurized or otherwise purified, in the liquid state	t+kcal
			132.00	3	Natural gas liquids	
				30	Natural gas liquids	
				301	Natural gasolene	t+kcal
				305	Natural liquified petroleum gas	t+kcal
				307	Other natural gas liquids	t+kcal
			132.00	5	Crude recovered sulphur	

Classes	Groups	Subgroups and items	NACE-ref	NIPRO-code	Description	Unit of measurement
				50	Crude recovered sulphur	
				500	Crude recovered sulphur (by-product of natural gas)	t
	133				Extraction of bituminous shale	
		133.0			Bituminous rocks	
			133.00		Bituminous rocks	
			133.00	1	Bituminous rocks (crude oil from bituminous minerals is classified to 131.00.130)	
				11	Bituminous rocks	
				110	Oil shale, oil chalk, bituminous sand and other bituminous rocks	t
				15	Shale oil, crude	
				150	Shale oil, crude (including dehydrated)	t
	134				Exploration for petroleum and natural gas	
		134.0			Oil and gas field exploration services	
			134.00		Oil and gas field exploration services	
			134.00	0	Oil and gas field exploration services	
				00	Oil and gas field exploration services	
				000	Oil and gas field exploration services	value
14	140				Mineral oil refining	
		140.1			Petroleum refining	

Classes	Groups	Subgroups and items	NACE-ref	NIPRO-code	Description	Unit of measurement
			140.11		Refining without distribution of petroleum products	
			140.12		Refining with integrated distribution of petroleum products	
			140.10		Petroleum refinery products	
					Note. The NACE makes, at the fifth digit level, a distinction between refineries with (140.12) and without (140.11) integrated distribution of petroleum products. This difference has been neglected here. The products of both five-digit positions have been classified in the NIPRO to 140.10	
			140.10	1	Light, medium and heavy oils	
				11	Naphthas	
				110	Naphthas	t
				12	Motor spirit	
				121	Regular-grade motor spirit	t
				123	Normal-grade motor spirit	t
				125	Aviation spirit	t
				13	Jet fuel and other kerosene	
				131	Burning oil	t
				133	Vaporizing oil	t

Classes	Groups	Subgroups and items	NACE-ref	NIPRO-code	Description	Unit of measurement
				135	Spirit type jet fuel	t
				137	Other jet fuel	t
				15	Diesel, gas oil and fuel oil	
				151	Light domestic heating gas and fuel oils	t
				155	Diesel oil	
				16	Residual fuel oil	
				160	Residual fuel oil	t
				17	Special spirits	
				171	White spirit	t
				175	Other special spirits	t
			140.10	3	Lubricating oils and other mineral oils, n.e.s.	
				31	Lubricating oils with various uses	
				311	Spindle oil	t
				314	Machine oil	t
				317	White oil	t
				33	Lubricating greases with a mineral oil content of 70% or more by weight	
				330	Lubricating greases with a mineral oil content of 70% or more by weight	t

Classes	Groups	Subgroups and items	NACE-ref	NIPRO-code	Description	Unit of measurement
				35	Lubricating preparations containing up to 70% mineral oil	
					256.60.111 = Lubricating preparations as auxiliary products for use in the textile industry	
					.511 = Lubricating preparations as auxiliary products for use in the leather and fur industry	
					259.20.109 = Other products for the care of leather	
					256.70.140 = Lubricating preparations as auxiliary products for the rubber industry	
					.319 = Lubricating preparations as protection products for the construction industry	
					.550 = Anti-rust preparations n.e.s.	
					.520 = Lubricating preparations n.e.s. (cutting oil, mould release oils, wire drawing oils and grease	
				37	Other mineral oil based lubricating oils	
				370	Other mineral oil based	
				[illegible]	Lubricating oil	t
				39	Other mineral oils not for lubricating purposes	

Classes	Groups	Subgroups and items	NACE-ref	NIPRO-code	Description	Unit of measurement
				391	Oils for metal treatment	t
				395	Insulating oils	t
				399	Mineral oils n.e.s. not for lubricating purposes	t
			140.10	5	Other mineral oil derivatives (excluding petrochemical products)	
				51	Vaseline	
				511	Crude vaseline	t
				519	Other vaseline (excluding medical and toiletery products)	t
				53	Paraffin-wax and paraffin-wax residues	
				531	Crude paraffin-wax	t
				534	Hard paraffin-wax (melting point above 45°C)	t
				537	Soft paraffin (melting point up to 45°C)	t
				539	Paraffinic residues	t
				55	Ozokerite, montan wax and peat wax, purified	
				550	Ozokerite, montan wax and peat wax, purified	t
				57	Other mineral oil derivatives (excluding gas and petrochemical products)	
				571	Bitumen	t

Classes	Groups	Subgroups and items	NACE-ref	NIPRO-code	Description	Unit of measurement
				574	Bituminous mixtures on bitumen base (e.g. mastic)	t
				577	Petroleum coke	t
			140.10	7	Liquified petroleum gas and refinery gas	
				71	Liquified petroleum gas (produced at refineries)	
				710	Liquified petroleum gas (e.g. propane-butane mixtures)	t+kcal
				75	Refinery gases (excluding natural gas)	
				750	Refinery gases (excluding natural gas)	m^3+kcal
			140.10	8	Crude recovered sulphur	
				80	Crude recovered sulphur	
				800	Crude recovered sulphur (from petrol refining)	t
			140.10	9	Residues from petroleum refining	
				90	Refining extracts and other residues from mineral oil processing (excluding those refining of lubricating oils)	
				900	Refining extracts and other residues from mineral oil processing (excluding those refining of lubricating oils)	t
		140.2			Processing of petroleum derivates (except petrochemicals)	

Classes	Groups	Subgroups and items	NACE-ref	NIPRO-code	Description	Unit of measurement
			140.20		Processed mineral oil derivatives or mixtures thereof (excluding petrochemical products)	
			140.20	1	Lubricating greases with a mineral oil content of 70% or more	
				10	Lubricating greases with a mineral oil content of 70% or more	
					140.10.330 = Lubricating greases with a mineral oil content of 70% or more	
			140.20	5	Other processed mineral oil derivatives or mixtures	
				50	Other processed mineral oil derivatives or mixtures	
				500	Bitumen emulsions	t
					140.10.311 = Spindle oil	
					.314 = Machine oil	
					.317 = White oil	
					.330 = Lubricating greases with a mineral	
					.370 = Other mineral oil based lubricating oils	
					.391 = Oils for metal treatment	
					.395 = Insulating oils	
					.399 = Mineral oils n.e.s.	

Classes	Groups	Subgroups and items	NACE-ref	NIPRO-code	Description	Unit of measurement
			140.20	9	Residues from processed mineral oil derivatives	
				90	Refining extracts and other residues from processed mineral oil derivatives	
				900	Refining extracts and other residues from processed mineral oil derivatives	t
15					<u>Nuclear fuels industry</u>	
	151				Extraction of ores containing fissionable and fertile materials	
		151.0			Ores containing fissile and breeder materials	
			151.00		Ores containing fissile and breeder materials	
			151.00	1	Uranium ores and pitchblende	
				10	Uranium ores and pitchblende	
				101	Uranium ores and pitchblende with a uranium content of more than 5% by weight	t-U
				105	Uranium ores and pitchblende with a uranium content of up to 5% by weight	t-U
			151.00	5	Thorium ores	
				50	Thorium ores	
				501	Monazite: uranium-thorianite and other thorium ores with a thorium content of more than 20% by weight	t-Th

Classes	Groups	Subgroups and items	NACE-ref	NIPRO-code	Description	Unit of measurement
				509	Other thorium ores	t-Th
	152				Production and processing of fissionable and fertile materials	
		152.0			Fissile and breeder materials	
			152.00		Fissile and breeder materials	
			152.00	1	Uranium and thorium concentrates	
				11	Uranium concentrates	
				110	Uranium concentrates (yellow cake and uranyl nitrate solution)	kg-U
				15	Thorium concentrate	
				150	Thorium concentrate	kg-Th
			152.00	3	Chemical elements and fissile and breeder isotopes, their compounds, alloys, dispersions and cermets, including mixtures thereof	
				31	Chemical elements, fissile and breeder isotopes, compounds and alloys of natural uranium	
				311	Uranium tetrafluorides	kg-U
				312	Uranium hexafluorides	kg-U
				313	Oxides	kg-U
				315	Crude metal (including swart and scrap)	kg-U

Classes	Groups	Subgroups and items	NACE-ref	NIPRO-code	Description	Unit of measurement
				316	Wrought metal	kg-U
				319	Other chemical compounds of natural uranium	kg-U
				32	Chemical elements, fissile and breeder isotopes, compounds and alloys of enriched uranium	
				321	Uranium tetrafluoride	kg-U+kg-U235
				322	Uranium hexafluoride	kg-U+kg-U235
				323	Oxides	kg-U+kg-U235
				326	Metal and alloys	kg-U+kg-U235
				328	Uranyl nitrate	kg-U+kg-U235
				329	Other chemical compounds of enriched uranium	kg-U+kg-U235
				33	Chemical elements, fissile and breeder isotopes, compounds and alloys of plutonium	
				330	Plutonium metal, its alloys and other chemical compounds	kg-Pu+kg-Pu241
				35	Chemical elements, isotopes, compounds, alloys, and mixtures of thorium	
				353	Oxides	kg-Th
				355	Crude metal	kg-Th
				356	Wrought metal	kg-Th
				359	Other chemical compounds of thorium	kg-Th
				36	Chemical elements, isotopes, compounds and alloys of depleted uranium	

Classes	Groups	Subgroups and items	NACE-ref	NIPRO-code	Description	Unit of measurement
				361	Uranium tetrafluoride	kg-U+kg-U235
				362	Uranium hexafluoride	kg-U+kg-U235
				363	Oxides	kg-U+kg-U235
				366	Metal and alloys	kg-U+kg-U235
				368	Uranyl nitrate	kg-U+kg-U235
				39	Mixed oxides, carbides, cermets, dispersions and alloys of uranium, plutonium and thorium	
				390	Mixed oxides, carbides, cermets, dispersions and alloys of uranium, plutonium and thorium	kg
			152.00	4	Non-irradiated fuel elements	
				41	Fuel elements with natural uranium	
				410	Fuel elements with natural uranium	kg-U
				42	Fuel elements with enriched uranium	
				421	Fuel elements with slightly enriched uranium	kg-U+kg-U235
				422	Fuel elements with greatly enriched uranium	kg-U+kg-U235
				43	Plutonium-containing fuel elements	
				430	Plutonium-containing fuel elements	kg-Pu+kg-Pu239.241
				46	Fuel elements with depleted uranium	
				460	Fuel elements with depleted uranium	kg-U+kg-U235

Classes	Groups	Subgroups and items	NACE-ref	NIPRO-code	Description	Unit of measurement
				49	Mixed fuel elements	
				490	Mixed fuel elements (uranium, plutonium, thorium) with various chemical compositions (oxides, carbides, nitrides etc.)	kg
16					<u>Production and distribution of electricity, gas, steam and hot water</u>	
	161				Generation and distribution of electric power	
		161.1			Generation of electricity from thermal energy (convention and geothermal)	
			161.10		Electricity from thermal power station (for public supply)	
			161.10	1	Electricity from conventional thermal power stations and by-products	
				11	Electricity from conventional thermal power stations	
				111	Electricity from hard coal and its derivatives	GWh
				112	Electricity from brown coal	GWh
				113	Electricity from non-gaseous petroleum products	GWh
				114	Electricity from natural gas	GWh
				115	Electricity from derived gases	GWh

Classes	Groups	Subgroups and items	NACE-ref	NIPRO-code	Description	Unit of measurement
				119	Electricity from other fuels	GWh
				15	Heat	
					163.00.104 = Steam, commercially distributed through pipes	
					.107 = Hot water, commercially distributed through pipes	
			161.10	2	Geothermal electricity	
				20	Geothermal electricity	
				200	Geothermal electricity	GWh
		161.2			Generation of electricity from hydraulic energy	
			161.20		Electricity from hydroelectric power stations (for public supply)	
			161.20	1	Electricity from hydroelectric power stations	
				10	Electricity from hydroelectric power stations	
				101	Electricity from natural flow	GWh
				105	Electricity from pumped storage	GWh
		161.3			Generation of electricity from nuclear energy	
			161.30		Electricity from nuclear power stations (for public supply)	

Classes	Groups	Subgroups and items	NACE-ref	NIPRO-code	Description	Unit of measurement
			161.30	1	Electricity from nuclear power stations and by-products	
				11	Electricity from nuclear power stations	
				111	Electricity from natural uranium reactors	GWh
				114	Electricity from enriched uranium reactors	
				117	Electricity from breeder reactors	GWh
				15	Heat	
					163.00.104 = Steam, commercially distributed through pipes	
					.107 = Hot water, commercially distributed through pipes	
				17	Irradiated fuel elements	
				171	Irradiated fuel elements of natural uranium	kg
				172	Irradiated fuel elements of enriched uranium	kg
				173	Irradiated fuel elements of plutonium	kg
				174	Irradiated fuel elements of depleted uranium	kg
				179	Irradiated fuel elements of mixed elements (uranium, plutonium, thorium)	kg
		161.4			Distribution of electricity	
			161.40		Distributed electricity (for public supply)	

Classes	Groups	Subgroups and items	NACE-ref	NIPRO-code	Description	Unit of measurement
			161.40	1	Distributed electricity (for public supply)	
				10	Distributed electricity (for public supply)	
				100	Distributed electricity (for public supply)	GWh
		161.5			Generation of electricity from thermal energy (conventional)	
			161.50		Electricity from conventional thermal power stations of self producers	
			161.50	1	Electricity from conventional thermal power stations of self producers	
				11	Electricity from conventional thermal power stations of self producers	
					161.10.111 = Electricity from hard coal and its derivatives	
					.112 = Electricity from brown coal	
					.113 = Electricity from non-gaseous petroleum products	
					.114 = Electricity from natural gas	
					.115 = Electricity from derived gases	
					.119 = Electricity from other fuels	
		161.6			Generation of electricity from hydraulic energy	

Classes	Groups	Subgroups and items	NACE-ref	NIPRO-code	Description	Unit of measurement
			161.60		Electricity from hydroelectric power stations of self producers	
			161.60	1	Electricity from hydroelectric power stations of self producers	
				10	Electricity from hydroelectric power stations of self producers	
					161.20.101 = Electricity from natural flow	
					.105 = Electricity from pumped storage	
		161.7			Generation of electricity from nuclear energy	
			161.70		Electricity from nuclear power stations of self producers	
			161.70	1	Electricity from nuclear power stations of self producers	
				11	Electricity from nuclear power stations of self producers	
					161.30.111 = Electricity from natural uranium reactors	
					.114 = Electricity from enriched uranium reactors	
					.117 = Electricity from breeder reactors	

Classes	Groups	Subgroups and items	NACE-ref	NIPRO-code	Description	Unit of measurement
				17	Irradiated fuel elements	
					161.30.171 = Irradiated fuel elements of natural uranium	
					.172 = Irradiated fuel elements of enriched uranium	
					.173 = Irradiated fuel elements of plutonium	
					.174 = Irradiated fuel elements of depleted uranium	
					.179 = Irradiated fuel elements of mixed elements (uranium, plutonium, thorium)	
	162				Gas works, gas distribution	
		162.1			Gas works	
					Note. Works gas production comprises gases from such undertakings whose main concern is the production and distribution of derived gases. Also included are gases resulting from cracking and mixing of other types of gas.	
			162.10		Works gas and gas-works coke	
			162.10	1	Works gas and gas-works coke	
				10	Works gas and gas-works coke	

Classes	Groups	Subgroups and items	NACE-ref	NIPRO-code	Description	Unit of measurement
				101	Works gas	m^3+kcal
				102	Gas-works coke (including low-temperature coke)	t
					102.30.173 = Crude tar	
					.175 = Crude benzene	
					.177 = Ammonium sulphate	
					.179 = Other by-products from coking of coal and lignite (ammoniacal liquor, spent gas cleaning substances)	
		162.2			Distribution of all types of gaseous fuels via mains	
			162.20		Gaseous fuels of any kind, locally distributed through low-pressure pipes	
			162.20	1	Gaseous fuels of any kind, locally distributed through low-pressure pipes	
				10	Gaseous fuels of any kind, locally distributed through low-pressure pipes	
				101	Natural gas unmodified (approx. 8,000-10,000 kcal/m^3)	m^3+kcal
				104	Works gas (approx. 4,000 kcal/m^3)	m^3+kcal
	163				Production and distribution of steam, hot water, compressed air; district heating plants	

Classes	Groups	Subgroups and items	NACE-ref	NIPRO-code	Description	Unit of measurement
		163.0			Piped heating (steam, hot water, district heating), piped compressed air	
			163.00		Piped heating (steam, hot water, district heating), piped compressed air	
			163.00	1	Piped heating (steam, hot water, district heating), piped compressed air	
				10	Piped heating (steam, hot water, district heating), piped compressed air	
				101	Compressed air piped	m^3
				104	Steam and heat (produced by district heating plants), distributed through pipes	Tcal
				107	Hot water (produced by district heating plants), distributed through pipes	m^3+tcal
	169				Production and distribution of several types of energy jointly	
					n.b. Because the products of this group are the same as those of 161, 162 and 163 they are not repeated here. The heading is established for the purpose of classifying enterprises and local units.	
17	170				Water supply: collection, purification and distribution of water	
			170.00		Water, collected, purified and distributed	

Classes	Groups	Subgroups and items	NACE-ref	NIPRO-code	Description	Unit of measurement
			170.00	1	Water, collected, purified and distributed	
				10	Water, collected, purified and distributed	
				100	Water, collected, purified and distributed	

Key

kg-U	kilograms of active uranium content
kg-Th	kilograms of active thorium content
kg-U+kg-U235	kilograms of active uranium or active uranium 235 content
kg-Pu+kg-Pu239.241	kilograms of active plutonium or active plutonium 239.241 content
t+kcal	ton or kilocalorie
t-U	tons of active uranium content
t-Th	tons of active thorium content

Annex VI

BUILDING UP THE BASIC DATA

1. In the main text of the Manual, it was pointed out that the compilation of an energy commodity balance (or energy commodity account) is necessary before an over-all energy balance can be constructed. This prior stage itself depends upon the existence of adequate and timely raw data on supplies, stocks, transformation and uses of each and every energy source of economic significance for the country concerned. Experience shows that this is not always the case, and whilst lack of data may be a particular problem in developing countries, other countries sometimes also do not have readily available all the statistical information they should. Further, in a number of countries in both groups, statistics arising from commercial, fiscal or administrative sources which appear from their customary description (e.g. sales, imports) to be suitable for the purposes of energy accounts may in fact be acceptable only as a starting point, but not as being really suitable for the purpose in hand. The following paragraphs consider some of the particular problems that arise and suggest ways of dealing with them.

2. Countries that produce, import or export crude oil and/or petroleum products will almost certainly possess fairly comprehensive statistics compiled by the producing, refining or trading corporations or other entities. The same is true mutatis mutandis with regard to coal, natural gas, hydropower and thermal electricity. There may be problems of compatibility between available statistics. These problems can occur because, at the different stages in the flow from the production or import of crude (or other primary energy) to the sale of finished products, each corporation will record information on stocks and flows on whatever basis most conveniently serves its own commercial purposes.

3. If, in the case of liquid fuels at one or more levels in the supply-and-use chain, crude and/or petroleum products are measured in volumetric terms (barrels or a multiple of the barrel), then different specific gravities for different products involve gains in volume (compared with the total volume of refinery input of crude) for products that are less dense than crude, and losses in volume for products that are more dense than crude. Further apparent gains and losses can occur if some volumetric statistics are recorded on the basis of actual temperature at the time of measurement, whilst other statistics are recorded after conversion of actual volumes to "standardized" volumes at (say) 60° F. Even when all volumes are recorded on the same temperature basis, quantities recorded by (say) a refinery as delivered to a marketing company may not be the same as the quantity reported by the marketing company as received from the refinery. Such discrepancies may arise because - apart from temperature factors - the marketing company may close its books on a different day in the month from that used by the refinery, or may exclude spillage and evaporation losses. The volumetric differences can be avoided if at all levels in the supply-and-use chain, a unit of mass (such as the imperial ton or the metric ton) is used rather than a volumetric unit (such as the barrel).

4. All sources of data should be studied closely to establish the precise meaning and coverage of each. The figures derived from different sources should be compared and any inconsistencies should be investigated with whoever is responsible for the release of figures for each statistical source. All explanation should always be recorded in writing, for reference and to avoid the need for repetition of an investigation by someone who is not aware of the previous work. (Quite apart

from special investigations of the sort outlined above, all returns should be checked as soon as possible after receipt, and any errors or inconsistencies should be referred to the person responsible for providing the data in question.)

5. Customs statistics are a by-product of the documentation required for the collection of taxes of various kinds on imports and exports of goods. Customs officers are not usually interested (because they do not need to be) in the measurement of physical flows, or change of ownership, that take place within each calendar month. Customs statistics are based on the volume or value of merchandise in respect of which taxes were paid or clearance certificates issued during each month, and the timing and pattern of these fiscal events will be somewhat later - sometimes much later - than the timing of the economic flows in which one is interested for the purpose of energy accounts.

6. Statistics obtained from energy producers and users may also sometimes not reflect as closely as one would wish the timing of energy stocks and flows. This can happen if the statistics are supplied by the Accounts Department rather than by the Supplies, Production or Marketing Department of the enterprise concerned. As with Customs documents, so also the timing of financial events (such as the issue of invoices or the settlement of accounts) will occur later than the physical events to which they relate.

7. This investigation of figures should be accompanied by examination of whether existing routine reporting forms supplied by (or customary progress reports and tabulations prepared within) commercial bodies are satisfactory from the following points of view:

(a) Clarity as regards what each cell entry should include and exclude and what calendar-dates bound the time-period to which the return relates;

(b) Completeness in that the form should be self-checking through containing, whenever possible, a full supply and/or use balance (e.g. opening stocks+imports -losses=disposals+closing stocks);

(c) Consistency between related returns (e.g. classifications of end-use sectors should as far as possible, be the same or be mutually reconcilable);

(d) Comprehensiveness in covering all energy flows and uses (e.g. not just confined to liquid fuels or to refinery transactions).

If need be, existing returns should be re-designed to include these features and new returns should be introduced to cover energy supplies and uses not covered by existing regular returns (e.g. fossil fuels, waste materials and hydropower used for auto-generation of electricity within industry.

8. The figures from checked (and, if need be, corrected) returns should be transferred onto suitably designed desk work-sheets that enable one to see at a glance the picture for each month compared with previous months. Such work-sheets should include tables that bring together stocks and flows outside, as well as within the principal producing or trading sectors (if, for example, there are direct imports of petroleum products by oil marketing companies, the electricity supply industry, or by one or more industries in the manufacturing sector). The detailed design of work-sheets will differ from country to country according to the features of its particular energy flows.

9. The terminology used in the commodity work-sheets is best kept, at least initially, to that used in the industry-specific returns from which the basic figures are derived. Consequently, broadly similar flows (e.g. production, trade, consumption) for liquid, solid, gaseous fuels, and for electricity, may be differently designated in each of the commodity work-sheets (e.g. refinery output, gross generation, net receipts, inland deliveries). In the Energy Commodity Account, however, a single set of row designations is used for all energy commodities.

10. Such monthly recording makes it possible to spot inconsistencies through time in figures that may be arithmetically correct if looked at in isolation within the month to which they relate: sudden jumps or falls from one month to another should arouse suspicion and lead to prompt investigation. Another benefit from building up monthly series is that they may reveal, with or without the use of formal statistical analysis, seasonal patterns that are of possible significance for policy purposes.

11. A further benefit from the compilation of monthly time-series is that they provide a data bank that may be drawn upon to compile a monthly bulletin of short-term indicators of energy supplies and uses. Such a bulletin could show, for example, statistics for the latest three months; the corresponding three months a year ago; the sum of each and the percentage change between this and the previous year; this year's cumulative total to date and the corresponding figure for last year; and the difference between them. A commentary could be added - and it should offer explanations (rather than verbal statements of what the figures themselves show such as ("... A went up by x and B went down by y ..."). Figures that are not readily available monthly may be included in a rotating series of quarterly or half-yearly tables (again accompanied by a suitable <u>explanatory</u> text).

12. When overall energy balances are produced on a regular basis, highly aggregated balances may be produced quarterly, and if this is possible, then mini-balance total rows at different levels could be made into time-series tables for the bulletin. It is likely that producers (e.g. electricity supply corporations) and distributors (e.g. oil marketing companies) will be interested in the different types of customer to whom they sell, as a basis for pricing and sales promotion. However, in the case of liquid and solid sources of energy (e.g. petroleum products, coal and on a smaller scale charcoal and firewood) that can be held in stock by a merchant or dealer who buys from the producer or from a large marketing company, these latter "upstream sellers" will not know to what type of final user their products are sold by the "downstream dealers". It may nevertheless be possible to include in the Bulletin quarterly or half-yearly tables showing a broad sectoral analysis of energy-purchasers.

13. Statistics on the distribution of each type of energy between final energy users are more difficult to obtain than data on energy supplies. This is so for several reasons but mainly because the more numerous the users are and the smaller the amounts of energy they consume, the less the practicability of attempting to record on a regular basis the quantities they use. But even for larger users (e.g. small-sized factories and workshops and other enterprises) the actual cost in terms of time and money of data collection may be excessive in relation to a Government's over-all statistical priorities.

14. The most effective way of finding out about the level and pattern of energy use when there are numerous smaller users is by means of suitably designed and

properly executed sample surveys. This applies particularly to the household sector. Sample surveys may also be appropriate in the case of transport, hotels and commercial sectors, and when estimating the contribution of fuelwood, animate energy (human and animal muscle power), and other traditional fuels to the economy. In some other cases (e.g. Government sector) an ad hoc census type of inquiry may be conducted in all ministries and associated bodies.

15. This is not the place to elaborate on the principles and procedures to be followed for sample surveys. The methodology of such surveys is a specialized subject in itself and, if their use is envisaged, the advice of a suitably qualified and experienced statistician should be sought at an early stage.

16. The general approach to the compilation and validation of basic energy statistics set out in the preceding paragraphs should of course also be adopted in the cases of other secondary energy sources such as coke, coke oven gas, solid fuel briquettes and town gas.

17. As has been pointed out in the main text of the present Manual, the construction of energy commodity accounts and over-all energy balances is not only an invaluable method for compiling a fully articulated set of energy statistics, but it also identifies gaps in the data currently available, provides an exacting test of the internal and external consistency of all the data both currently available and specially obtained, and helps to determine priorities for further work.

Annex VII

RELATIONSHIP BETWEEN SOME ENERGY TERMS

The following table shows the relationship between various designations currently used for classifying energy sources, and the particular sources that are covered by each description. The most satisfactory over-all working classification at present would seem to be: Commercial/Traditional/Non-Conventional/Animate.

Any such classification will need to be revised in ten or so years time when judgements about what is non-conventional may have changed. A more durable classification might perhaps be based on the closeness of the linkage between solar energy and each terrestrial energy source (e.g. direct solar, such as solar thermal and photovoltaics; directly-derived solar, such as wind, hydro, wave, fuelcrops, fuelwood and vegetable residues; indirectly-derived solar, such as charcoal, animal residues, biogas and alcohols; and, as separate non-solar sources, fossil, fissile, geothermal, tidal and animate energy sources). The degree of solar dependence of some of the sources is not immediately obvious, and a classification based on such dependence would seem unlikely to gain ready acceptance by many working energy statisticians and other analysts who are already accustomed to the sort of terminology set out in the following table. A priority need is to seek clarity and consistency in the use of the latter terminology.

RENEWABILITY: / CONVENTIONALITY	RENEWABLE	NON-RENEWABLE
Commercial	Hydropower (large scale) Geothermal	Fossil fuels Nuclear (other)
Non-commercial/ Traditional	Fuelwood cropping charcoal Twigs, leaves, sticks etc. Crop residues Animal residues Industrial residues Hydro (watermills) Wind (wind mills and pumps)	Fuelwood mining/ Charcoal
Newer	Other fuel crops (for alcohol etc.) Biogas Solar Tidal and wave Ocean thermal Hydropower (mini) Wind (wind motors)	Oil from coal
Animate*	Animal power Human power	

* Alternatively, animal energy could be classified as "traditional renewable" energy.

Annex VIII

ENERGY BALANCES FOR DEVELOPING COUNTRIES

The following two tables show, first, how a simplified energy balance might look for a developing country, and secondly, how a separate balance might be constructed to cover traditional and new renewable sources of energy. Where there is an input of, for example, petroleum products to agriculture for the production of fuel crops, this input should be included as part of "Energy sectors' own use", with a suitable foot-note, in the main energy balance and a corresponding foot-note should be added to the appropriate column in the "Renewables" balance.

Year:

Over-all energy balance for a developing country

Joules x 10^{12} (Terajoules) Delete one
Tonnes of oil equivalent (TOE) x 10^{3}

Source / Flow	Crude oil	Gasolene	Kerosene/ Jet fuel	Diesel	Fuel oil	Asphalt	LPG	Av.- gas	Ref- gas	Electricity: Thermal	Electricity: Hydro	Bagasse	Fuel- wood	Char- coal	Other	Total
1. Primary production																
2. Imports																
3. Exports																
4. Bunkers																
5. Stock change (rise(-)/fall(+))																
6. Inland supply 1+2-(3+4)+5																
7. Transformation: (input(-)/output(+))																
Refinery																
Electricity Generation:																
Public																
Sugar																
Bauxite																
Other a/																
Total																
8. Energy sector own use and loss																
Refinery																
Power stations																
9. Distribution loss																
10. Non-energy use																
11. Final energy use: 6+7-(8+9+10)																
Agriculture																
Bauxite																
Other mining and quarrying																
Sugar, molasses and rum																
Other food, beverages and tobacco																
Chemicals																
Other manufacture																
Transport																
Rail																
Road																
Air																
Distribution, commerce and finance																
Households																
Government services																
Hotels etc.																
Other																

a/ Specify coverage and distinguish main component(s), if necessary, in a satellite table (e.g. solar, wind, biogas sources/other industries).

Energy balance for renewable sources

Source / Flow	Fuel-wood	Fuelcrops a/		Agricultural residues		Charcoal	Alcohol	Biogas	Solar		Wind	Hydro-Power	Elec-tricity	Total
		Sugar cane	Other	Crop	Livestock				Thermal	Light				
Primary production														
Stock change														
Primary supply														
Transformation														
Charcoal production														
Distillation														
Fermentation														
Gas production														
Electricity generation														
Final energy use														
Agriculture														
Irrigation														
Drainage														
Drying and cooling														
Mechanical power														
Food processing														
Drying														
Heating and cooling														
Mechanical power														
Light														
Transport														
Domestic														
Cooking														
Light														
Other														
Other (specify)														
Residual														

a/ Corresponding final fuel input to crop production and harvesting.

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