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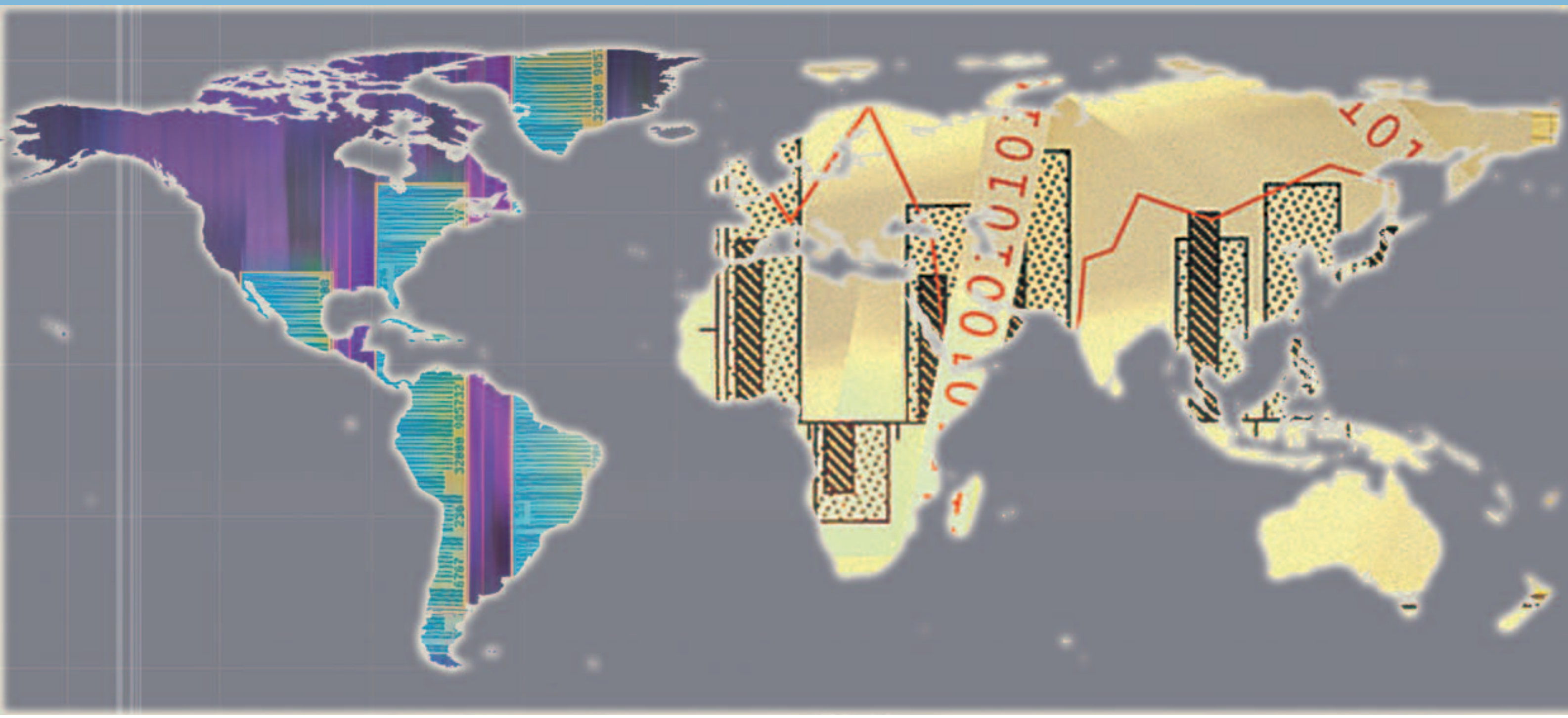

Compilation of Energy Statistics for Economic Analysis

UNITED NATIONS
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Acronyms and abbreviations

GDP	Gross Domestic Product
IEA	International Energy Agency
IRIS	International Recommendations for Industrial Statistics
ISIC	International Standard Industrial Classification of all Economic Activities
Ktoe	Kilo tonne oil equivalent
MHT	Medium High and High Technology Sectors
MVA	Manufacturing Value Added (GDP concept, unless otherwise stated)
NSO	National Statistical Office
OECD	Organisation for Economic Cooperation and Development
UN	United Nations
UNIDO	United Nations Industrial Development Organization
UNSD	United Nations Statistics Division

1. Introduction

The ancient *Veda* has described energy as one of the five basic elements[1] which made life possible on Earth. For millennia of human existence, mankind took energy for granted, because up to about 200 years ago all human needs for energy were fully met by renewable sources. Currently, more than 80 per cent of world energy consumption comes from fossil fuel, a finite and non-renewable source. Fossil fuel-based energy sources, primarily coal and oil, followed by natural gas, brought manufacturing to the mass scale of production. Today, manufacturing accounts for just above one quarter of total energy consumption world-wide but it has also produced a large variety of consumer goods which need yet another form of energy for exploitation. With the growing pace of industrialization, especially in developing countries with 80 per cent of the world's population, energy has been the major concern for sustainable development, environmental protection and a decent standard of living.

Energy and environment are the priority areas of UNIDO. The Organization promotes energy efficiency and encourages the use of renewable energy sources in industrial production, with the aim of mitigating climate change and making industry environmentally sustainable. UNIDO plays a leading role in energy related matters within the UN system. Energy has also been the main focus of the strategic research programme, which aims to analyze recent trends of production and use of energy and recommend the future direction of environmentally sustainable industrial growth through efficient use of energy in the industrial production process. Statistics plays an indispensable role in this process, as the formulation of industrial development strategy for today's diverse world can only be based on sound empirical evidence provided by reliable, accurate and internationally comparable statistics.

The industrial sector, according to the International Recommendations for Industrial Statistics[2], includes mining, manufacturing and electricity and gas and heat supply. Industry plays a dual role on the energy market - as a producer and as a consumer. Manufacturing has developed a new technology that increases efficiency of energy production and minimizes energy use in production of other goods and services. Industrial statistics provides a sound methodology for measurement of level, stricture, growth and efficiency of energy production and its use at macro and industrial sector level. Although, international practice of

[1] Veda (ref. *Ayurveda*) concluded that life has been possible on our planet thanks to the presence of all five basic elements (*pancha maha-bhoot*) namely - land (*sthal* or *prithvi*), water (*jal*), air (*vaayu*), energy or fire (*tej*) and space (*aakash*) together, which is not the case elsewhere in our solar system. *Aurveda* described the direct impact of these elements on the formation of the five senses of the human body.

[2] United Nations (2008): *International Recommendations for Industrial Statistics.*

collecting and disseminating energy data is not new, compilation of energy statistics, especially for economic analysis, has acquired new dimensions in recent years. Energy statistics, as available from different sources, lack compatibility which, in turn, limits the scope of economic analysis. Some international efforts have been made to build a complete energy account, however, many countries still lack the capacity of producing detailed energy data. Moreover, a basic methodological document, such as *International Recommendations for Energy Statistics* (IRES), which would set a standard for world-wide harmonization of energy statistics, has yet to be finalized. The classification standards for energy related activities and products are also still in the process of development.

UNIDO's industrial statistics database is the only data source that provides detailed structural statistics at the 4-digit level of ISIC. This database can be used to derive important indicators of structure and growth of manufacturing sectors in relation to production and consumption of energy. However, energy use data at the same level are not available. UNIDO Statistics have collected some data on energy cost from sample countries, which can be combined with existing industrial data in order to produce important estimates. This paper reviews the existing energy data sources and outlines some techniques of using currently available UNIDO data in combination with external sources as well as survey results.

2. Review of data sources

Energy, as a product of economic activities, comprises goods and incidental services related to fuel, heat and power. As any other commodity, energy is the result of production, such as extraction from mineral resources or transformation of materials and substances into a new product, which can be exchanged on the market or serve as input for production of other goods and services or be used for final consumption. Information about the total volume of energy available to a country for its intermediate and final consumption within a given period of time, can be obtained from the energy balance.

The scope of current studies on energy statistics is confined to the production of energy and its use as input for industrial production. The main task on the production side is to estimate output of energy producing sectors in order to measure its contribution to the total economy. In the course of transaction between different statistical units, energy commodities may appear as a product in one case and as input in another. Energy as input is an essential part of intermediate goods utilized in the production process. Therefore, an economic analysis of energy, in its dual role, requires data about the value of energy used in industrial production and its share in total intermediate consumption. Such data could also be used to estimate energy costs per unit of output. A comparative analysis of energy costs in value terms across the industrial sectors could reveal the relative advantage of production arising from the different levels of energy intensity.

International data sources on energy lack adequate statistics for construction of a full account of production and use of energy. Production data on energy are reported at a national level in physical units of measurement, whereas data for other commodities are widely available at an industrial sector level in value terms. Therefore, it is often difficult to relate these two data sets for economic analysis. In this chapter, we shall further examine the available data sources for production and consumption of energy.

2.1. Statistics of energy production

There are mainly two approaches for collecting and compiling statistics on energy production. The first approach is based on the industrial survey method. According to the *International Recommendations for Industrial Statistics, 2008* (as well as earlier versions), the scope of industrial statistics is confined to mining and quarrying, manufacturing, electricity, gas and water supply, which corresponds to sections B, C, D and E of *International Standard Industrial Classification of all economic activities, revision 4.* The energy sector, as defined in the current statistical practice, comprises all economic units whose principle activity is related to extraction, production, manufacturing, transformation or distribution of energy products. Hence, all economic activity units classified to the energy sectors fall within the scope of industrial statistics and are, therefore, covered by regular industrial surveys.

Table 1: Classification of Energy sectors by ISIC in correspondence to Industrial sectors

Energy sector	**ISIC Division code**		**Major industrial sector**
	Revision 3	**Revision 4**	
Mining of coal and lignite; extraction of peat	10	05	Mining and quarrying
Extraction of crude petroleum and natural gas	11	06	Mining and quarrying
Mining of uranium and thorium ores	12	07	Mining and quarrying
Manufacture of coke, refined petroleum products and nuclear fuel	23	19	Manufacturing
Electricity, gas, steam and air conditioning supply	40	35	Electricity, gas, steam and air conditioning supply

Data obtained for the energy sector from regular industrial surveys are collected and compiled according to the national accounts concepts. Similarly, production of energy is measured by the value of output of a statistical unit, primarily engaged in an economic activity related to production of energy goods for the market. Together with production variables, the survey data also includes number of establishments/enterprises, employment and wages and salaries. UNIDO has been collecting these data for manufacturing, mining and utility sectors, within the framework of international data collection and the exchange programme endorsed by the UN Statistical Commission, since 1993. So far, these data were transferred to the United Nations Statistics Division (UNSD) without further processing. However, in 2009, the Statistics Unit of UNIDO has started its own compilation of mining and utility statistics. A pilot publication of world statistics on mining and utilities for international users is currently being prepared and expected to be disseminated in 2010.

Production data for energy statistics can be derived from two separately maintained UNIDO databases. From the industrial statistics database (INDSTAT4) and the mining and utility statistics database (MINSTAT3). A prototype statistical table, as it could be compiled for selected countries and years, from the above-mentioned two databases, is illustrated below.

Table 2: Summary of statistics of energy sectors in UNIDO database Romania, 2004

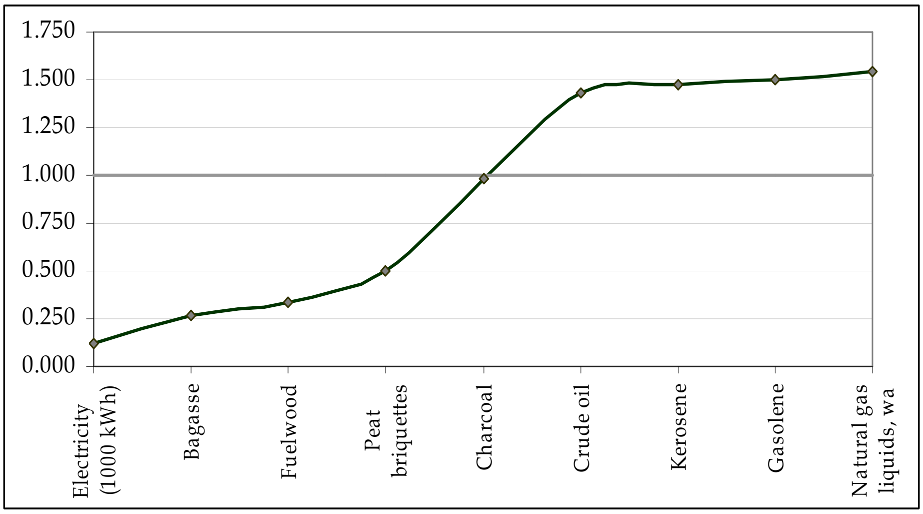
ISIC		Number of enterprises	Number of employees	Value added at producer's prices (in million Lei)
102	Mining and agglomeration of lignite	56	13038	647.1
103	Extraction and agglomeration of peat	9	…	0.6
111	Extraction of crude petroleum and natural gas	28	52971	4751.5
112	Services incidental to oil and gas	113	2643	776.2
120	Mining of uranium and thorium ores	…	…	…
231	Coke oven products	…	…	…
232	Refined petroleum products	30	8675	306330
233	Processing of nuclear fuel	…	…	…
401	Production and distribution of electricity	175	53926	4055.8
402	Manufacture and distribution of gaseous fuels	107	51454	730.3
403	Steam and hot water supply	98	27667	292.4

Source: UNIDO Statistics Database;
… *Not applicable or data not available*

Variables in the above tables present the characteristics of statistical units (enterprise or establishments depending on a country's practice) engaged in production of energy commodities as their main activity. The main advantage of these data is that energy sectors are observed within the overall economic spectrum and statistical indicators are presented with respect to relative importance of energy production to the total economy. Employment and value added data form an important basis for economic analysis of growth, structure and productivity in energy sectors in comparison with other economic activities.

The second approach defines energy as a commercially produced commodity available on the market. Production measures in this case are primarily based on physical properties of commodities. Generally, a national energy balance is maintained at macro level, which provides data on the flow of energy commodities including production, export, import and change in stocks. Production flow data are presented by source or type of energy commodities as they appear on the market. Energy production data based on this approach is compiled and disseminated by UN Statistics Division through the *Energy Statistics Yearbook*, latest edition of 2006. This *Yearbook* presents the production data by forms of energy commodities: solid, liquid, gas and electricity. Each form of commodity is measured in natural units, such as mass and volume, suitable to its physical state. In order to derive the total amount of production, a conversion factor is used to bring all sources of energy down to a common denominator, based on the calorific value of fuels. In case of primary electricity, an equivalent is found through the amount of coal or oil required to produce a unit of thermal electricity. The conversion coefficients vary by type of fuel and electricity as shown below.

Figure 1: Standard conversion coefficients of coal equivalent by type



Source: UN Energy Statistics Yearbook, 2006

The use of a common unit allows summing up energy production generated from different sources and in different forms. This is particularly important in the present context when efforts are made to utilize renewable energy sources in replacement of those based on fossil fuels. For statistical purposes, the renewable energy sources are listed in the following groups:

Solid:	Fuel wood, charcoal, bagasse
Liquids and gases:	Bio-diesel, alcohol, bio-gas and steam, heat for geo-thermal sources
Electricity:	Geo-thermal, hydro, solar, wind and wave sources
Wastes:	Animal, vegetal, municipal and pulp and paper wastes

However, international sources do not provide complete and reliable data on production of energy from renewable sources. An overall estimate of IEA shows an approximately 15 per cent share of renewable sources of total world energy production in 2007[3].

Despite some increase in production, the share of renewable sources of total energy supply has not changed significantly over the last 30 years. Statistics on overall demand and supply of energy are available at an aggregated level. Table 3 presents data on the world energy flow which are also available by country:

[3] *Key World Energy Statistics 2009,* IEA, Paris.

Table 3: World energy flow by commodity type for selected years
Million metric tons of coal equivalent

	2003	**2004**	**2005**	**2006**
Solids	3495.6	3786.7	4037.0	4254.1
Liquids	5425.1	5630.3	5722.4	5768.2
Gas	3551.0	3640.0	3740.6	3866.7
Electricity	672.2	707.5	728.7	749.5
Total primary energy production	**13144.0**	**13764.5**	**14228.7**	**14638.6**
Change in stock	7.7	14.3	2.9	77.0
Import	5721.2	6119.1	6280.5	6438.3
Export	5652.4	6043.5	6265.9	6445.6
Bunkers	360.9	387.6	414.2	430.3
Apparent consumption	**12859.5**	**13466.9**	**13832.0**	**14278.0**
Unallocated[4]	284.5	297.6	396.7	360.6

Source: UN Energy Statistics Yearbook, 2006

Due to the high concentration of energy production in a small number of countries/regions, especially those based on fossil fuels, domestic energy production of large number of other countries amounts to only a tiny share in their energy demand. Therefore, it is essential that domestic production data are presented together with export and import figures. Statistics of energy flow also include the figures on stock and those remained in aviation and marine bunkers. The apparent consumption of energy of a country, which is a balancing item, is derived from production, external trade and changes in stock.

Statistics on demand/supply balance, by energy sources and by country, are compiled and disseminated by the United Nations Statistics Division in its publication - *The Energy Balances and Electricity Profiles* - latest publication 2006. Simultaneously, OECD also disseminates energy balance data through its separate publications for OECD and non-OECD countries. OECD publications have more detailed breakdowns of energy consumption data for the manufacturing sectors.

[4] The figure is derived as a difference between production and apparent consumption, thus does not match with the source, which employs different computation.

2.2. Statistics of energy consumption

Similar to the production side, statistics of energy consumption can be compiled from industrial survey results as well as from energy balances. The survey data provides value of energy consumption of a statistical unit in the production process, which is a part of intermediate consumption in the national account concept. Most countries, with a regular industrial survey system in place, collect data on energy cost incurred in the industrial production process. The General Industrial Statistics Questionnaire, currently implemented by UNIDO, has no separate breakdown of input to present statistics of energy consumption. However, industrial statistics programmes of the national statistical offices do include energy related data items in the annual survey questionnaire. In order to derive some ratio estimates of energy use in manufacturing, in 2009, the Statistics Unit of UNIDO has made a request for energy input data to a number of countries. Out of 60 countries in a sample, which represented both industrialized and developing countries, data could be collected for 50 countries (Annex-3). While non-OECD countries responded directly, data for OECD countries were retrieved from STAN database. This exercise once again confirmed the availability of energy input data for a large number of countries. As an illustration, distribution of energy consumption by manufacturing divisions is presented in Table 4, which has been compiled from data provided by the Central Statistical Office of India based on results of the Annual Survey of Industries, 2005/06.

Data on the costs of energy, when presented together with total input and value added, provide essential information for economic analysis within the overall framework of economic accounting. One of the most important information these data can produce is the variation of energy cost by manufacturing activities. For example in India (Table 4), non-metallic mineral products (ISIC 26), which contributed less than 5 per cent of total value added of manufacturing, accounted for 13 per cent of fuel and 9 per cent of electricity consumption. Share of textile and basic metal sectors in energy consumption was also higher than their share in value added. On the contrary, such high-technology sectors, as electrical and electronic products, medical and optical instruments and production of machinery and equipment, had a much higher share in value added compared to energy input.

The limitation of currently available industrial survey data is that it does not provide a cost breakdown by type of energy sources. A general distinction is often made between fuel and electricity. However, there are finite and renewable sources in both types. Even with selection of renewable sources, economists distinguish between the cost paid by producers and the cost borne by society at large. For example, the cost of charcoal, which is considered a renewable source, may be the lowest in many developing countries, but its social cost is quite high in the context of deforestation and subsequent environmental degradation. Through the analysis of survey data, it is possible to point out which sectors are high or low energy-intensive, but it would not be possible to suggest the relative advantage of using one energy source over another in different industrial activities.

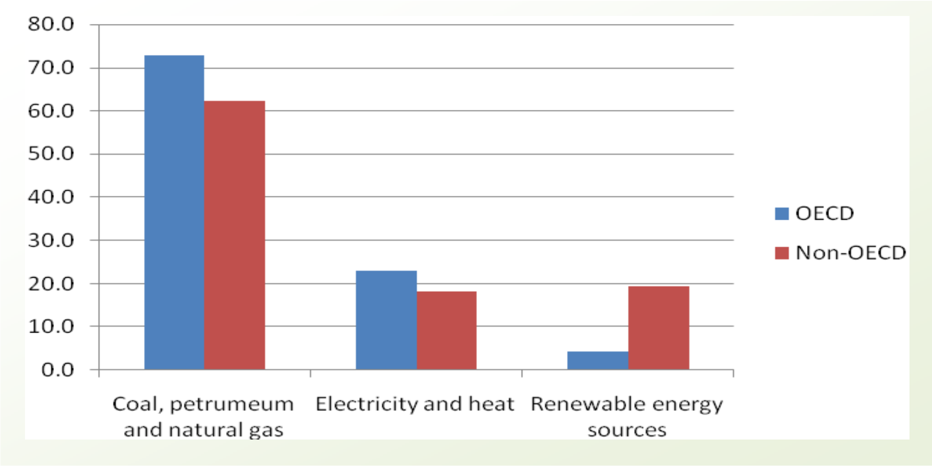
Table 4: Percentage distribution of energy costs, total input and value added of manufacturing sectors in India by ISIC, 2006

ISIC		Cost of		Total input	Value added
		Fuels	Electricity		
15	Food and beverages	7.8	8.2	13.5	7.8
16	Tobacco products	0.2	0.2	0.5	1.6
17	Textiles	11.7	15.5	7.0	6.7
18	Wearing apparel, fur	0.7	0.9	1.5	1.7
19	Leather products	0.5	0.6	0.9	0.6
20	Wood products	0.2	0.3	0.3	0.2
21	Paper and paper products	3.2	2.7	1.3	1.5
22	Printing and publishing	0.4	0.6	0.8	1.4
23	Refined petroleum, nuclear fuel	4.4	1.1	16.6	13.4
24	Chemicals and chemical products	17.5	11.9	12.4	16.2
25	Rubber and plastics products	2.9	3.9	2.9	2.5
26	Non-metallic mineral products	13.0	9.2	2.6	4.5
27	Basic metals	28.1	33.4	13.7	14.3
28	Fabricated metal products	1.9	2.0	2.7	2.8
29	Machinery and equipment n.e.c.	1.8	2.4	5.0	5.6
30	Office and computing machinery	0.1	0.1	0.4	0.8
31	Electrical machinery and apparatus	1.1	1.5	3.6	3.8
32	Radio, television	0.5	0.6	1.9	1.7
33	Medical and optical instruments	0.2	0.3	0.5	0.9
34	Motor vehicles	2.2	2.8	6.3	7.6
35	Other transport equipment	1.1	1.3	2.7	3.0
36	Furniture and other manufacturing	0.4	0.6	2.7	1.3
37	Recycling	0.0	0.0	0.0	0.0
	Total	100.0	100.0	100.0	100.0

Source: Central Statistics Office of India (UNIDO aggregation at 2-digit ISIC)

UNSD and IEA provide consumption data by types of energy sources. IEA data are available in broad division of OECD and Non-OECD countries. IEA data are often presented in combination with different energy sources, which complicates direct estimation of figures for renewable energy. Overall distribution of world energy consumption by source can be presented by three major groups as shown in the graph below.

Figure 2: **Percentage Distribution of Final Consumption of Energy by type of sources, 2007**



Source: IEA database

More than two-thirds of demand is met by fossil fuel based energy products in both country groups. The share of renewable sources in total final consumption was higher in non-OECD countries. This could be explained by the fact that in developing countries, which are mostly represented in the group of non-OECD countries, energy needs are mainly met by bio-fuel, in order to maintain a basic livelihood for the vast majority of the a rural population. In the case of industrial consumption of energy, the share of renewable sources was higher in OECD countries.

The limitation of energy consumption data, as it is available in UNSD and IEA databases, is that they are reported in physical quantities, similar to the production side. Therefore, it is not possible to make(produce) a direct cost analysis from these data.

However, energy consumption quantities can be related to volume based macroeconomic indicators in order to produce statistics on energy use for cross-country comparison.

For example, GDP and MVA at constant prices, or an index of industrial production refer to the volume of production and their change reflects the real growth. Similarly, an index of energy consumption can be constructed directly from the data reported in physical quantities. Usually a comparison of two such indices is made for analysis of energy efficiency.

At the same time computation of indicators, involving two separate databases, require that some precautions are taken with regard to data comparability. Quite often data may refer to different reference periods or different target populations. For a number of countries, where UNIDO database showed the presence of industrial activities, energy consumption value was missing in the IEA database. In another case, a large-scale activity had underreported consumption data in corresponding IEA data. This inconsistency arises from the use of different national data sources in obtaining industrial and energy data. In order to avoid such inconsistencies in volume measures, preference in data analysis in this paper is given to ratio or indices.

2.3. Statistics of relative energy use

For the purpose of international comparison, production and consumption indicators of energy should be analysed with respect to the size of an economy, often measured by GDP, and population of a country. UNIDO Statistics maintains a national accounts database, which includes: GDP and MVA at current and constant prices, population and exchange rates of national currencies to the US dollar. In combination with energy statistics, these data are used to estimate the major indicators of relative energy use for a large number of countries and country groups. Data for GDP and other variables at macro level are readily available, also from other national and international data sources, in relatively long time-series. For this reason, a large number of reports and publications are widely available with extensive analysis at the macroeconomic level.

However, similar analysis at the sector level is limited. Although the IEA database provides energy consumption statistics for manufacturing at ISIC 2-digit level, its coverage of non-OECD countries with sub-sector breakdowns is limited. UNIDO has started production of a new database at the 2-digit level of ISIC, which presents data by 23 manufacturing branches. IEA sector breakdown for energy consumption is limited to 11 branches (see Annex-1 for detail comparison). It is also necessary to take some precautions when using UNIDO data in time-series, due to valuation of output measures at current prices. The suggested approach is to derive the share coefficients by sector from INDSTAT-2 and apply it to MVA data at constant prices which are available for a large number of countries and long time-series.

3. Statistical indicators of energy efficiency

The term energy efficiency can be examined in terms of technological and economic efficiency (Parkin and Bade, 2001). Technological efficiency indicates the least possible quantity(amount) of energy input, to the point where it is no longer possible to increase output without also increasing energy input. Economic efficiency, on the other hand, implies that the quantity of required energy per unit of output may not be decreased, whereas the costs can be reduced in various ways. Hence, whatever proves technologically efficient will always be economically efficient; which demonstrates rationality when aiming for economic efficiency of energy use in industrial production processes.

Available data do not allow a “clean” analysis of economic or technological efficiency. Measurement of technological efficiency requires segregated data for the required energy input and industrial production, in physical quantities at product level. However, it is nearly impossible to obtain such data from official statistics. Energy use data are normally collected from establishments which can provide information for energy use of the total production process, including energy used by ancillary activities, such as office and administration as well as transportation and storage facilities of a given production unit. Similarly, overall energy consumption data is available only in physical quantities, and their conversion to value requires differentiated price data from industrial and household use. There are also some difficulties in obtaining accurate price data, because the market prices deviate considerably from their basic prices due to the complex system of national taxation and subsidies on energy products. Despite the preference given to measurement of economic efficiency in concepts, this paper presents the indicators based on both value and quantity measures of energy use.

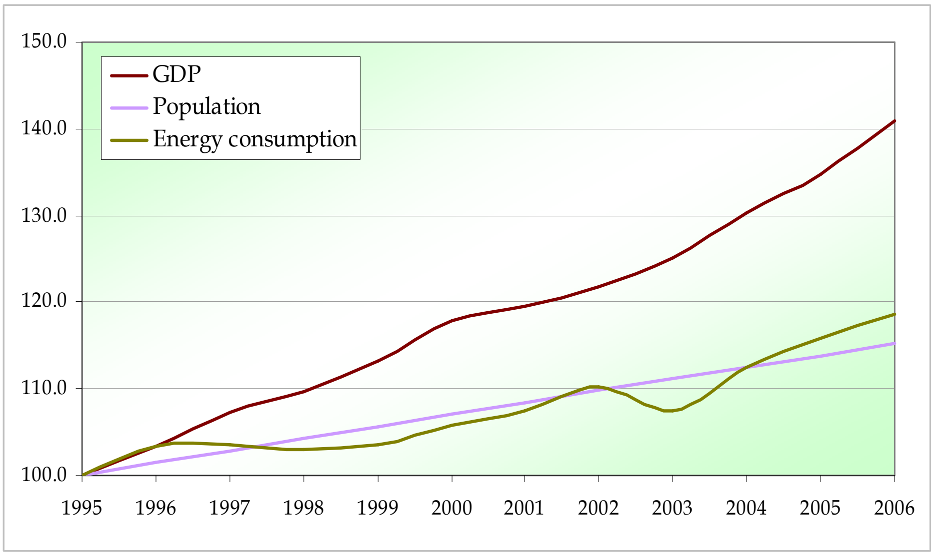
3.1. Macroeconomic indicators of energy use

At macro level the statistical indicators are constructed to measure the consumption of energy as an intermediate input to the production process as well as an essential commodity of final consumption by households. On this basis total energy consumption can be compared to the size of an economy, given by GDP, as well as the size of population. Following indicators are commonly used for this purpose:

1. Total energy consumption per unit of GDP and its relative change
2. Proportion of final and intermediate consumption of energy
3. Final energy consumption by households per capita and its growth
4. Energy consumption by sectors (manufacturing, transport, etc)

Comparison of total energy consumption figures with GDP (at constant prices) and population over a period of time helps reveal the trend of energy use efficiency in the simplest way. For instance, the following chart presents the growth trend of world energy consumption together with GDP and population.

Figure 3: Growth of world energy consumption, GDP and Population 1990=100



Source: UNIDO database and UN Energy Statistics Yearbook, 2006
GDP at constant prices 2000

The world population growth remains steady and predictable for decades. At the same time energy consumption has grown faster than population, showing that the energy demand of an average individual today is higher than it was two decades ago. On the production side, however, economic growth is much higher than total energy consumption. From this two important conclusions can be drawn:

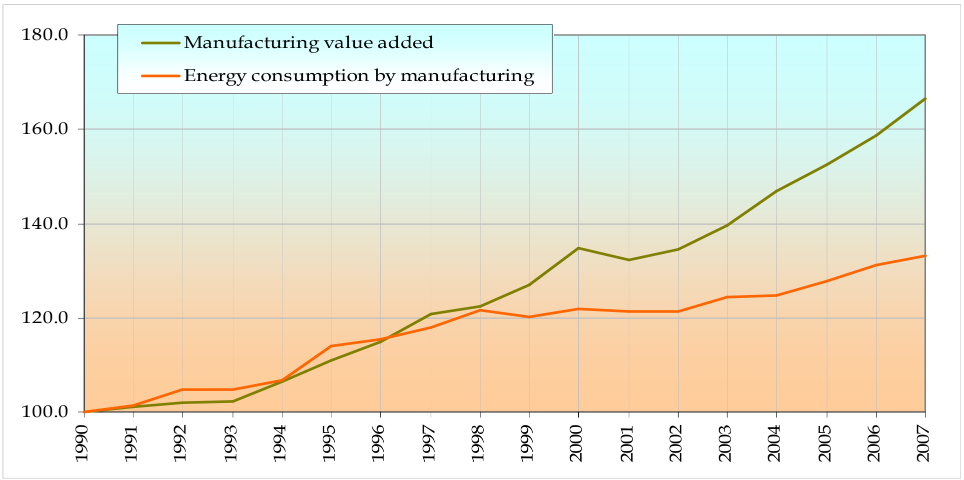
- Energy needs of production**,** as an intermediate input, do not increase proportionally to economic growth thanks to rising energy efficiency.
- Economic growth, on the other hand, changes the expenditure pattern of the population with an increased demand for modern goods and services, which consumes more energy.

Hence, the challenge is not only to increase energy efficiency in industrial production, but also to produce energy efficient consumer goods.

The variety of energy sources available for household consumption is just as wide as it is for industrial consumption; however, the scope of renewable energy in household consumption comprises a far wider range. Energy intensity of households is also related to housing construction, transportation and service sectors, which are not within the scope of this paper.

In case of manufacturing, energy consumption during the last two decades has grown much less than output. The graph presented below is based on the fixed based indices of world MVA at 2000 constant US$ and energy consumption (including energy used in transformation) in Kilo tonnes of oil equivalent (Ktoe).

Figure 4: Comparative growth of world industrial production and energy consumption, 1990=100



Source: UNIDO database and *IEA*

From the growth trends depicted above it is evident that in general world manufacturing is gaining in relative energy efficiency. However, there are several other dimensions of this change. First, energy intensity varies by kind of industrial activities and countries. Second, conditions of energy use are quite different for countries depending upon their access to and possession of energy sources. The task of statistics is to assess the data sources and produce energy efficient indicators at a more detailed level for comparative analysis across sectors and countries. Further, we present some statistical indicators based on relation of energy input to industrial output at sector level.

3.2. Energy intensity

One of the major indicators of energy efficiency, based on the relation of energy input and output, is energy intensity, which is the ratio variable calculated as energy use per unit of output given by:

$$E(\text{int})_t = \frac{E_t}{Y_t} \qquad (1)$$

where:

E_t - is total consumption of energy by manufacturing sector for *t* year
Y_t - net output of manufacturing or MVA for *t* year.

Energy intensity is reduced when production increases per unit of energy use, or when less energy is used for the same amount of production. In both cases, energy intensity is in inverse relation to energy efficiency. As the energy intensity is analyzed mainly in time dimensions, research interest is not so much in measurement of absolute energy consumption, but of dynamics of energy efficiency. For this purpose, a fixed-base index of energy intensity can be constructed from the relation of the index of energy use to the index of output.

Thus, the index of energy intensity is given by;

$$I_{E(\text{int})} = \frac{I_{Et}}{I_{Yt}} \qquad (2)$$

which can be easily derived from: $I_{E(\text{int})} = \left(\frac{E_1}{Y_1} : \frac{E_0}{Y_0}\right) = \left(\frac{E_1}{E_0} : \frac{Y_1}{Y_0}\right)$

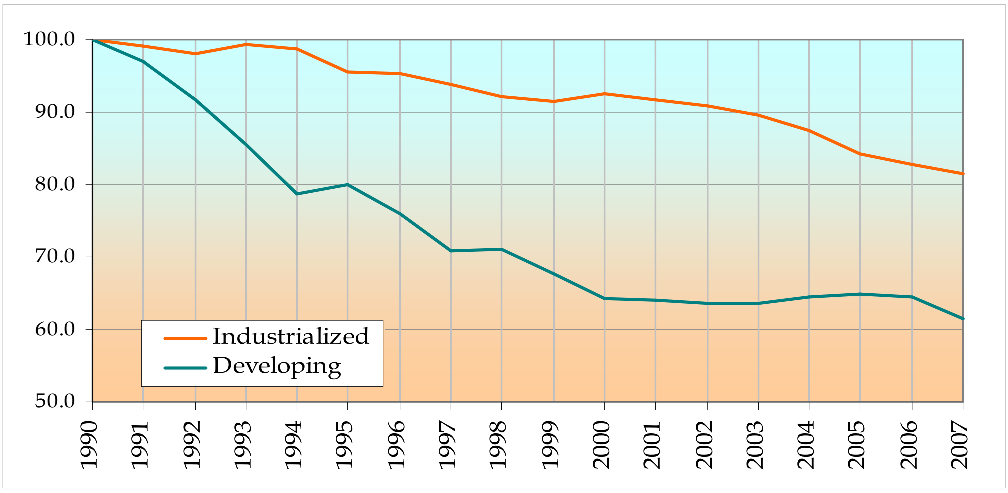
where:

$I_{E(\text{int})}$ - Index of energy intensity
I_{Et} - Index of energy consumption, and
I_{Yt} - Index of output (normally value added)

Despite the limitations mentioned earlier, in terms of number of countries covered in the IEA database, it represents most of the economies with a dominant share in industrial production and energy consumption in both groups: industrialized and developing countries[5].

Available statistics suggest a systematic decline of energy intensity in industrialized as well as in developing countries. Energy intensity in industrialized countries has decreased by almost 20 per cent in the last two decades. During the same period developing countries have decreased energy use per unit of production by almost 40 per cent. Massive expansion of industrial production in many developing countries was instrumental for introduction and development of new technologies and improvement of productivity. Falling energy intensity also suggests that industrial growth in developing countries is not merely of an extensive nature, but also has the elements of innovation, and efficiency.

Figure 5: Energy intensity change in manufacturing industry of industrialized and developing countries, 1990-2007



Source: UNIDO database and *IEA*

Energy intensity trends of both country groups were computed from the energy consumption data of IEA and MVA data of UNIDO.

[5] Country groupings in this paper under *Industrialized* and *Developing* correspond to the groupings applied by UNIDO Statistics. For details see Appendix I of *International Yearbook of Industrial Statistics* 2010.

3.3. Decomposition of energy intensity

When sector data are available, the energy intensity expressed in formula (1) can be decomposed in order to measure the effect of sector level energy intensity and structural change on overall energy intensity. For this purpose, formula (1) is expanded as follows:

$$E(\text{int})_t = \frac{E_t}{Y_t} = \sum \frac{E_{i,t}}{Y_{i,t}} \frac{Y_{i,t}}{Y_t} = \sum E(\text{int})_{i,t} \; s_{i,t} \qquad (3)$$

$$s_{i,t} = \frac{Y_{i,t}}{Y_t}$$

where:

$E(\text{int})_t$	- Energy intensity for total manufacturing for year *t*
$E(\text{int})_{i,t}$	- Energy intensity for i-th manufacturing sector for year *t*
$s_{i,t}$	- Share of i-th sector in total MVA

Equation (3) can be differentiated with respect to time in order to obtain the value of change of energy intensity. However, this process may be quite complicated to calculate. An approximation of the same measure can be obtained from an additive model of the following form:

$$\lambda E(tot) = \lambda E(ind) + \lambda E(str) + \varepsilon \qquad (4)$$

where:

$\lambda E(tot)$	- change of total energy intensity of manufacturing in two periods derived as; $E(\text{int})_1 - E(\text{int})_0$
$\lambda E(ind)$	- change of energy intensity arising from the change in energy intensities in sectors
$\lambda E(str)$	- change of energy intensity as a result of structural change
ε	- residuals or unexplained change.

Existing literature on intensity (Ang, B.W. and S.Y. Lee, 1994 and other studies on this topic in following years) suggests several methods of decomposition, out of which the Parametric Divisia Method 2 (PDM2) was chosen for this paper. This method is simple to use and has led to quite similar results as with other methods. Expression of PDM2 for decomposition is given by:

$$\lambda I(ind) = \sum \left[E(\text{int})_{i,0} + \alpha_i (E(\text{int})_{i,t} - IE(\text{int})_{i,0}) \right] \times \left(s_{i,t} - s_{i,0} \right) \quad (5)$$

$$\lambda I(str) = \sum \left[s_{i,0} + \beta_i \left(s_{i,t} - s_{i,0} \right) \right] \times (E(\text{int})_{i,t} - E(\text{int})_{i,0}) \quad (6)$$

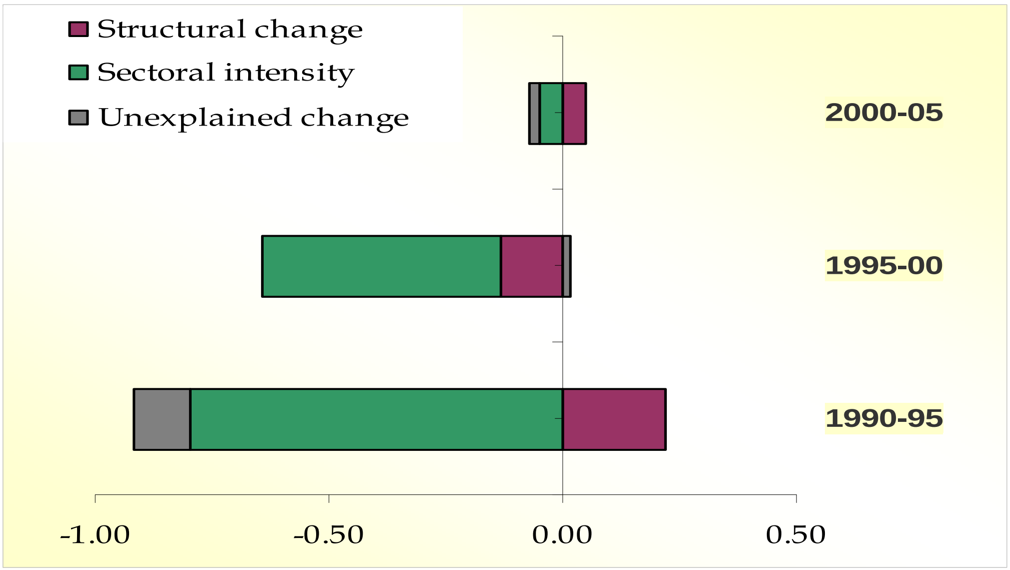
Depending upon the value specified for parameters α and β above expression yields different results. For $\alpha = \beta = 0$, we obtain Laspeyres fixed base index, which means that the change of a given variable is measured by keeping others fixed for the base year period. For $\alpha = \beta = 1$, the results will correspond to the Paasche method, which measures the change of a given variable while keeping others at the current year level. Sometimes, a middle approach is applied with $\alpha = \beta = 0.5$.

Calculation of structural change was done in terms of sector distribution of manufacturing output, for which data are available in the UNIDO database. Consumption of energy by manufacturing sector was taken from the IEA database. However, IEA only provides quite aggregated data and does not exactly match with ISIC even at the 2-digit level. For some countries, IEA database combines energy consumption of different sectors or unclassified industries under *Not specified*. Therefore, application of the above methods in practice should precede some exercise on data preparation/ transformation.

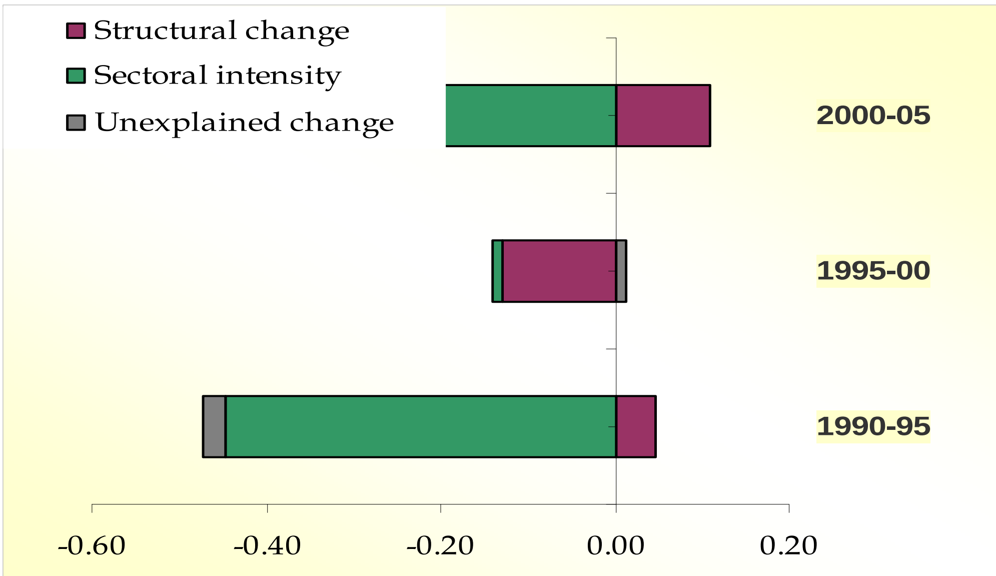
Changes of energy intensity at the sector level mainly indicate the technological efficiency of energy use as a result of introduction of more energy efficient technology or better organization of production processes directed to energy savings.

Figure 6: Factor values of energy intensity change in manufacturing industry

a. China



b. India



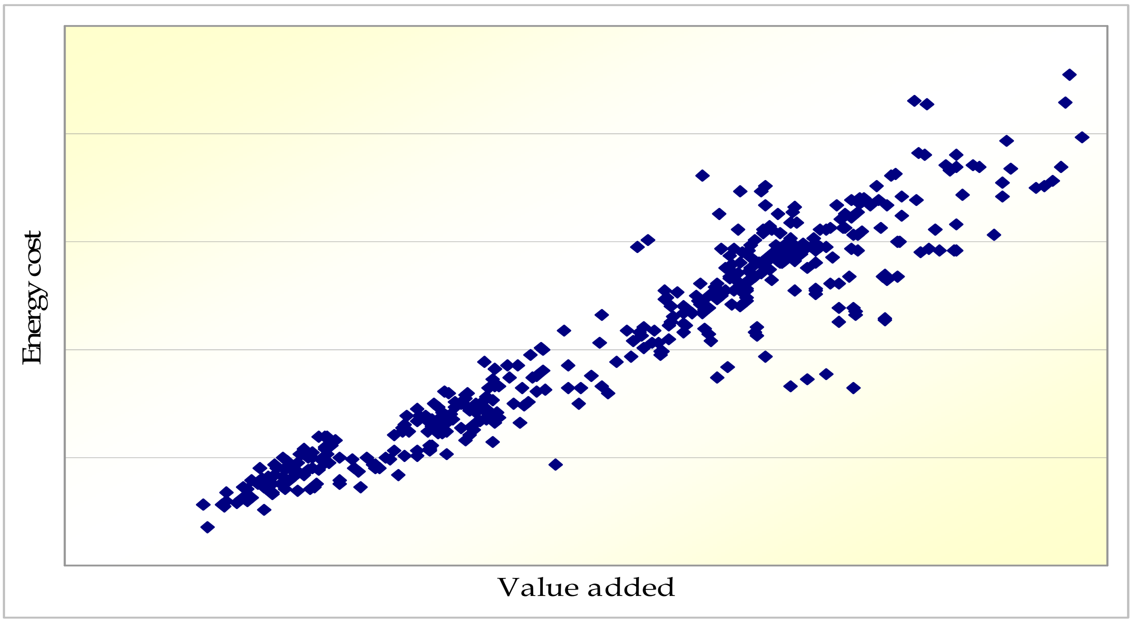
Source: Calculations by the author based on UNIDO data on output and its structure by manufacturing branches; IEA data on energy use

Reduction of energy intensity contributed by structural change accounts for economic efficiency. In this case the sector shift takes place in favour low energy intensive sectors. Both in China and India, energy intensity changes were mainly contributed by the sector driven take-off that took place in the 1990's. Earlier studies also have concluded that this systematic decline of energy intensity in China was primarily due to the contribution of the sectors of intermediate production, rather than structural changes (Hu, 2005). Similarly, the overall energy-intensity change in India was mainly achieved by a significant decline in highly energy-intensive raw materials, such as non-metallic mineral products and basic metals (Mukhopadhyaya, K, Chakraborty D, 2005).

3.4. Value added produced per unit of energy cost

This coefficient differs from the energy-intensity as it indicates the amount of output produced per unit cost of energy (not energy quantity). The energy input and value added data by manufacturing sectors, from a sample of developing countries, indicate a convincing linear relationship between these variables. However, linearity could only be revealed after log-transformation due to cross-country and cross-sector variations. The scatter diagram below depicts the change-pattern of value added produced per unit of energy input.

Figure 7: Dependence of value added on energy input in selected developing countries



Source: UNIDO statistics

Value added produced per energy input is a convenient and highly effective measure of economic efficiency of for energy use, thanks to the existence of a direct correlation between the variables. At the levels of industry or industry group (ISIC 4-digit level) it can be calculated simply as:

$$VA / energy\_input = \frac{y_k}{x_K} \qquad (7)$$

where:

y_k - value added at k-th level of industry/industry group
x_k - cost of energy at k-th level

Data collected from the results of annual industrial surveys of selected countries showed significant variations of value added/energy input ratio by manufacturing branches. The highly technology-intensive sectors, such as office equipment and computers, electrical machinery and medical and optical instruments, produced a considerably high amount of value added per unit of energy input, whereas non-metallic mineral products, basic metals and chemical industries were more energy intensive. For a generalized measure from larger observation, a regression model would be more appropriate. Since the relation of these variables has already been established as linear, a simple regression equation of the following type can be considered:

$$y_j = a + bx_j \qquad (8)$$

where:

y_j – value added of *j*-the manufacturing sector
x_j – energy cost of j-th sector.

The parameter *b* indicates how much value added may change on average, if energy input is changed by unit. Inversely, *b* can also be used as an estimator/predictor[6] for the required amount of energy input needed to increase value added by unit. The above equation was applied with a *set to* 0 to sample data from developing countries in order to estimate the average energy cost per unit of value added. Results indicated

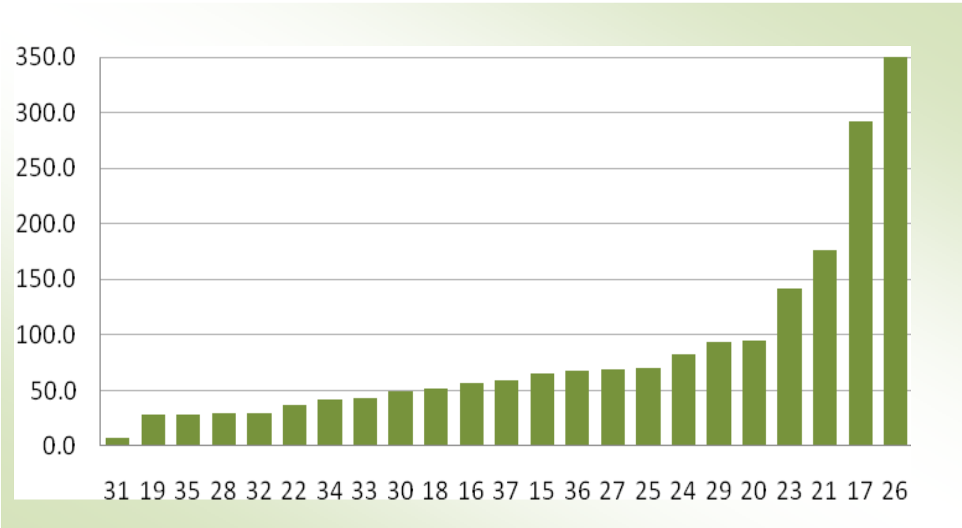
[6] The parameter *b* as an estimator may find wide application for statistics obtained from INDSTAT database of UNIDO. In our example of food manufacturing (ISIC division 15), value of *b* was 0.066. The energy cost for food manufacturing of a developing country with value added equivalent to US$ 570 million can be estimated as:

$$x_{15} = \frac{y_{15}}{b} = \frac{570}{15.2} = 37.2$$

Hence, for value added of US$ 570 million, the required energy cost will be US$ 37.2 million.

highly varying amounts of energy input by sectors. Figure 8 depicts the amount of energy required per 1000 units of value added, which was obtained from the inverse value of the *b* parameter. As a generalized predictor *b* expresses the relation between two variables, so they can be applied irrespective of the currency units in which output and input data are reported.

Figure 8: Value of energy input required for production of 1000 unit of value added in developing countries by ISIC



Source: UNIDO Statistics
Manufacturing branches are ranked by value of regression parameter
Description of ISIC codes is given in Annex – *1*

Estimated value of energy input per unit of value added was highest in non-metallic mineral products. For production of net output, say US$ 1000, cost of energy input is estimated at about US$ 350. However, the energy cost for production of the same amount of value added in electrical and electronic products would be much less than US$ 50. Most of the low energy-intensive sectors are those classified to medium-high and high technology (MHT) sectors. The cross-sector variability is also analyzed in terms of energy input ratio.

3.5. Energy input ratio

This ratio indicates the share of energy cost in total input or intermediate consumption. The terms “total input” and “intermediate consumption” are often interchanged, even though there is a difference in the way of data collection and the compilation methods employed. Input is often used in industrial statistics which covers the cost of all goods and services purchased by an establishment during a reference period and can, in the broadest sense, be classified into: i) materials and supplies; ii) energy; iii) industrial and non-industrial services. Input may not include the cost of some additional services purchased at the enterprise level, which are adjusted in the process of compilation of the production accounts for estimation of GDP and other macroeconomic variables. In this paper, reference is made to input for which data are available from the annual industrial surveys.

The energy input ratio is calculated as relation of energy cost to total input of manufacturing activities.

$$e_j^m = \frac{x_j}{C_j^m} \qquad (9)$$

where:

e_j^m - energy input ratio
x_j - cost of energy
C_j^m - total input

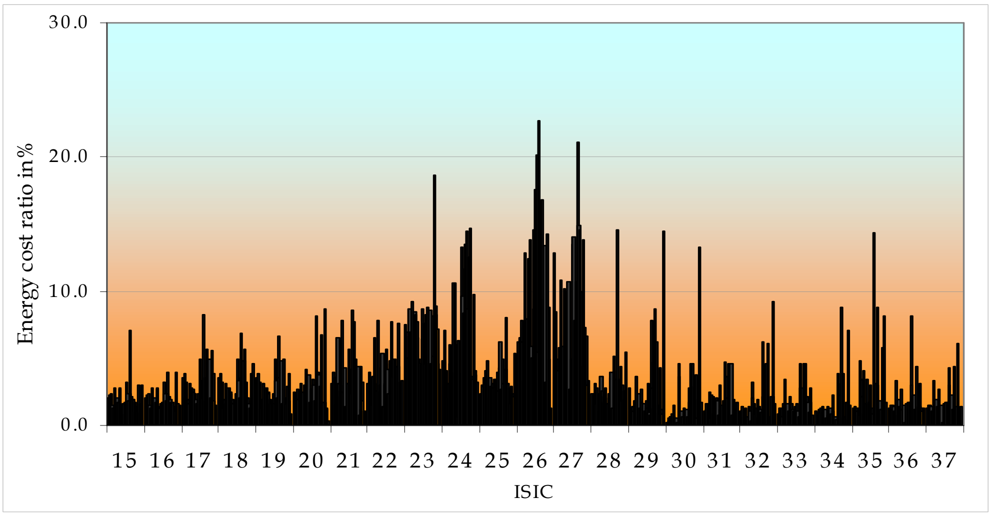
Suffix *j* stands for a manufacturing sector.

Using the industrial survey method, energy cost comprises the cost of fuel and electricity. Actual consumption of fuel is derived from the purchase of fuel during a given year at purchasers' prices and change in stock. The value of electricity consumed by an industrial establishment is calculated as the difference between the value of electricity purchased and sales to a third party of its own generation. Electricity generated for self-consumption is included in the electricity balance of an enterprise but not in production costs. Omission of this item may underestimate energy costs at the firm level, but at the sector level its share is quite negligible.

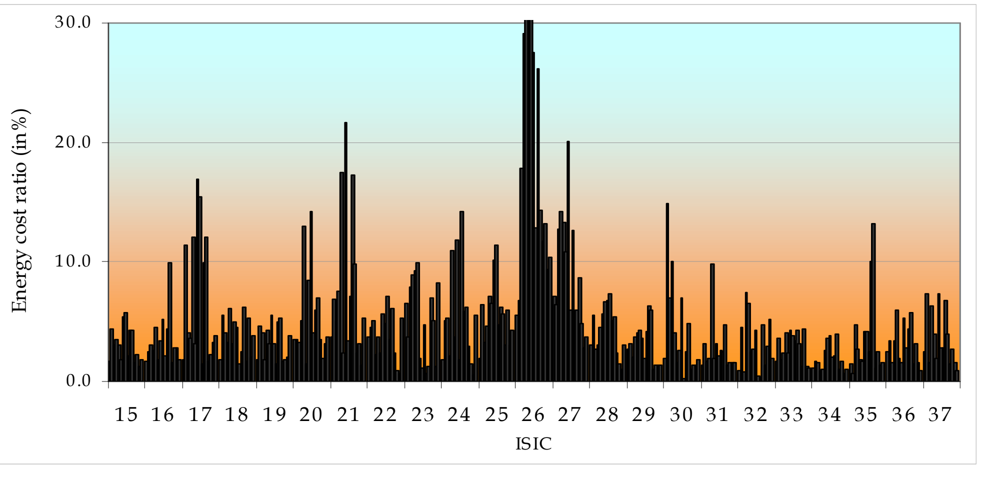
To study the cross-sector variation of energy input ratio, UNIDO Statistics collected industrial survey data from a sample number of industrialized and developing countries. Data for industrialized countries were obtained directly from NSOs as well as from the OECD Stan database. For developing countries all data were reported by NSOs from their annual industrial surveys. There were a few comparison problems in the two data sets because STAN database presents energy data in a format of input-output tables, which redistributes energy costs by type of products. In the case of developing countries, data relate to total energy costs of establishments which, in turn, combine energy costs of main and allied activities. Therefore, these data had to be used in relative measure of sector-wise energy intensity within country groups rather than across country groups. Data collected from the above mentioned sources were supplemented with our own estimates, especially when original data required combination of or split to ISIC groups. In the final set of data used in analysis, energy input ratio varied by sectors as shown below. Highest energy consumption was found in ISIC 26 and lowest in ISIC 30 in both country groups.

Figure 9: Energy input ratio of manufacturing industry by ISIC division

a. Industrialized countries



b. Developing countries



Source: UNIDO statistics (*Description of activities for ISIC codes at 2-digit level is given in annex*)

4. Classification of manufacturing sectors by energy input ratio

Currently available data, especially for manufacturing output (UNIDO database) and energy consumption (IEA database), are fit for a growth and structure analysis of (on)energy intensity. However, a benchmark study requires more consistent and fully compatible data generated from a single source. As a preliminary exercise to this end, we use the survey data collected by UNIDO Statistics which refer to a single target population. These data have been used to develop a classification of manufacturing sectors by the energy input ratio. This classification is based on the ranking of manufacturing branches at the 2-digit level of ISIC Rev3.

For this purpose, manufacturing branches of each sample country were ranked by energy input ratios. Ranking was made separately for developing and industrialized countries due to considerable differences in energy input ratios between these country groups. Each sector within a sample country got a score in the range of 1 to m. An overall rank coefficient was computed as:

$$\tau_j = \frac{\sum_i z_{ij}}{Z_{\max}}; \quad i = \overline{1, n} \quad j = \overline{1, m} \qquad (10)$$

where;

τ_j – rank score of j-th industry in i-th sample country

$z_{\max}$ – maximum value of z; i.e. (m x n)

m – number of manufacturing branches at 2 digit level of ISIC; $(m = 23)$

n - number of countries in sample.

In the end, sectors were arranged by rank score to identify highest to lowest energy intensive ISIC branches. Results thus obtained were compared to the mean energy ratio calculated as a harmonic mean of sector values of energy input ratios, which is given by:

$$Mean\ Energy\_ratio = \frac{n}{\sum_i \frac{1}{x_i}} = \frac{No.\,of\ \ observations}{\sum_i \left(\frac{Input}{Energy\_\cos t}\right)_i} \qquad (11)$$

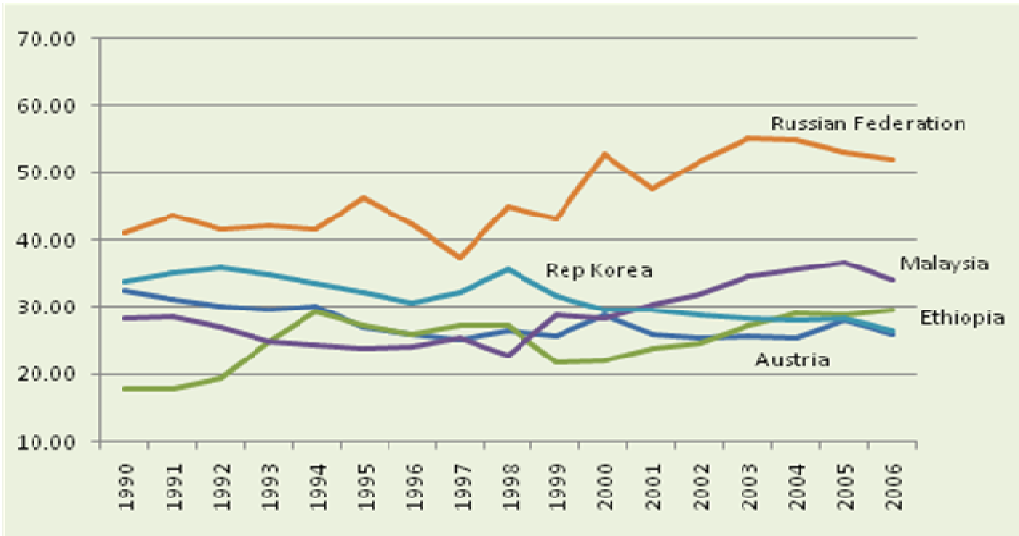
Values of mean energy ratios across the sectors produced the identical to that of rank coefficients. After comparison of the results of both exercises, manufacturing branches were classified into three categories of energy intensity (Annex-2).

Number of manufacturing sectors is presented at the 2-digit level of ISIC Revision 3.

Classification categories	Number of manufacturing sectors
High energy-intensive	6
Moderate energy-intensive	7
Low energy-intensive	10

For a more consistent distribution of total energy consumption among industry groups, it was necessary to include more sectors in the low-energy intensive groups. The most important outcome of this classification is the possibility of using available data in time-series with a benchmark ratio of energy input. It will not only indicate the energy intensive manufacturing sectors, but also reveal those countries where energy-intensive industries are dominant and persistent.

Figure 10: Share of high-energy intensive sectors in total value added selected countries



Source: UNIDO statistics

The dominance of energy intensive sectors was significant for a country like the Russian Federation, where the share of manufacturing activities related to processing of mineral resources, such as non-metallic minerals and basic metal products, is relatively high. However, in recent years shares of these sectors had a downward tendency, except in least developed countries like Ethiopia. High-energy intensive sectors had a lower share in countries where high technology sectors account for most of the manufacturing output.

5. Conclusion

Energy statistics, currently disseminated by different international agencies, are not compatible with each other in terms of target population, national data sources and methods of classification. It seriously limits the possibility of data analysis on energy use in the industrial sectors. However, analyses of growth trend can be done at least on the macroeconomic level by using data compiled from national energy balances. The international statistics community has taken a number of important steps to address these problems. Ongoing efforts with publications on *International recommendations for energy statistics* and its subsequent implementations may lead to harmonization of energy statistics across countries.

Based on review of data sources described in this paper, we suggest that data items related to production and use of energy by manufacturing establishments should be part of the regular industrial survey programme. An industrial survey questionnaire, implemented by a good many countries, includes a wide range of data items on value and quantity of energy production and use by industrial enterprises. These data are processed and compiled by NSOs however, they are not available internationally. The future direction of collecting energy statistics for international dissemination could be the expansion of the general industrial statistics questionnaire, by including energy related data items. Statistical methods have already been extensively applied for economic analyses in different contexts. The paper did not focus much on suggesting one or another method but dwelt upon applying existing methods to internationally available data, complemented with survey data directly collected by UNIDO Statistics. The classification of industries, suggested in the paper, allows the use of existing industrial statistics databases for the purpose of energy related analysis.

The main task of energy statistics, with respect to manufacturing activity, is to measure the level and pattern of energy use. Energy intensity changes over time and varies significantly by types of economic activities and across countries. Statistics provide an accurate measurement for such variations, which is instrumental to the correct assessment of efficiency in energy use. This paper has been prepared on the basis of limited data from a small sample only. For a more comprehensive analysis, aimed to discover the economic and technological efficiency of energy use, data collection should be extended to a larger sample of countries. Obviously, accuracy of statistical estimates depends largely on the number of observations and representativeness of countries in both dimensions – development groups and geographical reasons. Until a regular and comprehensive international data source on energy use for the industrial sectors is put in place, a direct survey method is the only option for obtaining the necessary data.

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Appendix 1
Corresponding industry groups UNIDO and IEA databases, ISIC rev 3

ISIC	Description of activities	
	UNIDO database	**IEA database**
15	Food products and beverages	Food and tobacco
16	Tobacco products	
17	Manufacture of textiles	Textile and leather
18	Wearing apparel; dressing and dyeing	
19	Manufacture of leather products	
20	Wood and wood products	Wood and wood products
21	Paper and paper products	Paper, pulp and print
22	Printing and publishing	
23	Coke and refined petroleum products	Petrochemical industry
24	Chemicals and chemical products	Chemicals and chemical products
25	Rubber and plastic products	*No corresponding industry group*
26	Non-metallic mineral products	Non-metallic minerals
27	Manufacture of basic metals	Iron and steel
		Non-ferrous metals (2720 and 2732)
28	Fabricated metal products	Machinery
29	Machinery and equipment n.e.c.	
30	Office and computing machinery	
31	Electrical machinery and apparatus n.e.c.	
32	Radio, TV and communication equipment	
33	Medical, precision and optical instruments	*No corresponding industry group*
34	Motor vehicles, trailers and semi-trailers	Transport equipment
35	Other transport equipment	
36	Furniture and other manufacturing n.e.c.	*No corresponding industry group*
37	Recycling	*No corresponding industry group*
	Rubber and plastic products *Medical, precision and optical instruments* *Furniture and other manufacturing n.e.c.* *Recycling*	Combined to the group of *Non-specified*

Appendix 2
Industry classification based on energy consumption intensity

Intensity of energy consumption	ISIC	Description of activities
High energy-intensive	17	Manufacture of textiles
	21	Paper and paper products
	23	Coke and refined petroleum products
	24	Chemical products
	26	Non-metallic mineral products
	27	Manufacture of basic metals
Moderate energy-intensive	15	Food products and beverages
	18	Wearing apparel; dressing and dyeing
	19	Manufacture of leather products
	20	Wood and wood products
	22	Printing and publishing
	24	Rubber and plastic products
	28	Fabricated metal products
Low energy-intensive	16	Tobacco products
	29	Machinery and equipment n.e.c.
	30	Office, accounting and computing machinery
	31	Electrical machinery and apparatus n.e.c.
	32	Radio, TV and communication equipment
	33	Medical, precision and optical instruments
	34	Motor vehicles, trailers and semi-trailers
	35	Other transport equipment
	36	Furniture and other manufacturing n.e.c.
	37	Recycling

Appendix 3
List of countries in sample from which energy input data were collected

1	Argentina	26	Jordan
2	Australia	27	Korea, Republic of
3	Austria	28	Latvia
4	Azerbaijan	29	Luxemburg
5	Bangladesh	30	Mauritius
6	Belgium	31	Netherlands
7	Brazil	32	Norway
8	Canada	33	New Zealand
9	China	34	Pakistan
10	Czech Republic	35	Poland
11	Denmark	36	Portugal
12	Ecuador	37	Russian Federation
13	Estonia	38	South Africa
14	Finland	39	Singapore
15	France	40	Slovakia
16	Germany	41	Spain
17	Greece	42	Sri Lanka
18	Hong Kong	43	Sweden
19	Hungary	44	Switzerland
20	India	45	Taiwan, China
21	Indonesia	46	Thailand
22	Ireland	47	Turkey
23	Israel	48	United Kingdom
24	Italy	49	Uruguay
25	Japan	50	United States

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