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ANALYSIS OF THE ENERGY SECTOR IN RELATION TO INDUSTRIALIZATION SCENARIOS FOR THE YEAR 2000

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FOREWORD

This study is intended to contribute to UNIDO Project No. US/82/033A, "Development Strategies and International Policy Alternatives," by analyzing the relationship between global industrialization and the energy sector.

Modeling the impacts of various stages of development and industrialization patterns on the energy sector requires three types of information. First, a demand-determined analysis of the industrial sector is necessary to provide information on how the stage, volume, and mode of production influence the energy requirements of each industry. Second, knowledge of present energy resources enables us to estimate maximum possible future energy supplies, which will constrain energy requirements from a geological or environmental point of view. Third, the feedback effect of energy supply as regards the rest of the economy is given by the capital requirements of the energy industries.

The terms of reference of this study (see Annex 1) called for three complementary stages:

- The first was to be a historical analysis of energy intensities in major energy-intensive industrial branches, following the "oil shocks" of the 1970s – i.e., the relative price changes of energy.
- The second was expected to be a series of medium- and long-term scenarios of industrial development to the year 2000; these scenarios to incorporate not only the major conclusions of the sectoral studies emerging from the historical analysis but also the macro-economic implications of energy prices.
- The third was to derive policy implications of the scenarios with respect to the industrialization process of developing countries.

In addition to these three major components, the study was also to assemble a few materials available in IIASA on estimates of future availabilities of energy supplies for the years 1990 and 2000 and related investment costs. These have been used in the scenarios and are available in the study, as well as IIASA forecasts of energy prices.

The historical analysis and the scenarios are given as Part I and Part II of the study respectively. A number of policy conclusions are mentioned in the course of the study but major conclusions are discussed in Part II (scenarios) and summarized at the outset of this report.

Part I aims at analyzing changing energy/output ratios for the most important energy-intensive industries. Previous studies at the International Institute for Applied Systems Analysis (IIASA) (e.g., Doblin (1983) and Lager (1983)) show that energy intensities vary with changes in the production structure. Also, a team using the UNIDAD model checked whether industrial specialization (at the 24-sector level) was responsible for the observed spread of input–output coefficients (at the 8-sector level): in 40 out of 64 coefficients it was found that output mix did have some effect. The present study therefore emphasizes product-mix effects and shows that changes in production structure affect the energy/output ratios of industry groups over time, as well as between countries. A detailed, disaggregated approach was chosen, not only on theoretical grounds but also for practical reasons. The use of commodity data requires more information but makes it possible to utilize engineering data. Data expressed in physical units are used for the most part, thus avoiding as far as possible problems relating to different currencies and discrepancies between exchange rates and individual purchasing power parities. Finally, the use of commodity market data provides a link between the energy demand profiles presented here and other studies dealing with special commodity markets.

All the above results have been used in the UNIDAD model runs until the year 2000. Some adjustments have been made in different scenarios with respect to the changes in the pattern of international trade between North and South.

Under the supervision of Anatoli Smyshlyaev, this report was prepared by Jacques Royer and Christian Lager. Ryoichi Nishimiya and Wolfgang Schöpp were responsible for the computational efforts. Thanks are also due to Claire Doblin and Michael Kraus for worthy suggestions and to Bruno Amable for reference work.

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SUMMARY AND CONCLUSIONS

This study is divided in two parts, with an historical analysis as Part I and, based on results from the analysis, a forward-looking exercise as Part II.

Part I.

The historical analysis firstly concentrates on the sharp decline in energy intensities (Terajoule per 1970$ of GDP) observed in industrial production of major developed economies after 1973. The econometric method used in the study is applied, for illustration purposes, to time series in Austria (see Chapter I.2). An original feature of the method is the possibility of incorporating engineering data in the analysis at the commodity level, where macroeconomic information is generally not available. The analysis refers to five energy-intensive industries and tries to explain changes in the price elasticity of energy intensity in each industry from 1964 to 1980. What is considered as a price-elasticity of energy in most studies, is decomposed here into two components, energy savings due to technical progress and impact of change in product mix. The product-mix effect is seen to explain a significant portion of the price elasticity (40% and above) in four industries out of five.

The analysis is then extended in Chapter I.3 to five energy-intensive branches of eight major industrialized countries of North America (USA), Western Europe (Austria, France, Federal Republic of Germany, Italy, UK), Eastern Europe (Hungary), and Japan. The annual rate of change in energy intensity in the 1970s is firstly computed and found to be generally negative, roughly ranging from −1% to −4% per annum. Identifying some fifteen specific commodities produced by these branches, it is then demonstrated that the decline in energy intensity can be explained to a large extent (measured in the study) by a shift of output towards the less energy-intensive commodities within each branch.

Two alternative interpretations suggest themselves, for policy purpose, the shift in output-mix towards less energy-intensive commodities can be thought to be permanent, i.e., related to a long-term move, or temporary, i.e., due to a cyclical slowdown of the economy. The importance of this issue cannot be underestimated, since a permanent shift of industrialized economies towards less-intensive commodities would strongly affect the international division of labor. Unfortunately no general answer can be given at this stage in an analysis restricted to the 1970s (the picture will be much clearer when the recession is over), but the report already offers a few interesting conclusions. In some cases, e.g., for non-ferrous metals in the Federal Republic of Germany, some qualitative evidence of temporary changes is found. The case of Iron and Steel, which is quantified in the study for seven countries, is yet of a different type. A permanent shift towards less-intensive processes, which can be assimilated to a long-term technical progress suggests that little ground, if any, is prepared in the seven developed countries for a new international division of labor in steel.

The next step is an attempt to extend the geographical coverage of the study to the world at large, divided into ten regions (the 11 UNITAD regions less Centrally Planned Economies of Asia on which few data were available). For this purpose, the production of fifteen commodities was analyzed in 80 countries over the eleven years from 1970 to 1981. In carrying out this huge data-processing reported in Chapter I.4, many statistical traps were encountered, sometimes involving arbitrary choices. However, an attempt was made to compare production figures obtained in the sample of countries with independent world estimates, which, on the whole, confirmed the results. The main finding, at this stage, was that most developing countries increased their world shares in the production of energy-intensive goods. Whether this fast industrialization process in the primary processing industry was intended primarily to their domestic markets or to the international market is open to interpretation at this stage, and the potential future impact of these alternatives on the international division of labor is left for Part II to investigate.

Next (Chapter I.5), energy requirements of these commodities were computed on the basis of two simplified rules:

(1) The energy intensity of a specific commodity or of a homogeneous group of commodities does not differ very much between countries (best practice prevails).

(2) Energy saving technological progress grows with a constant exponential growth rate, which differs from industry to industry, but is equal among countries.

The computation of energy requirements, again, was checked through the energy balances of the industrial sector in those countries where relevant time series are available. In Chapter I.6, the result of the analysis appears in the form of energy-intensity coefficients for five sub-sectors (chemical industries, non-ferrous metals, steel, non-metallic mineral products, pulp and paper) and for the primary processing sector as a whole in each of the ten regions. An econometric procedure similar to the test carried out in preceding chapters is used to measure the shift towards more (or less) energy-intensive commodities within each subsector in each region, from 1970 to 1981. In developed regions, massive evidence of a shift towards less energy-intensive products is found, except in the natural-resources endowed "Other Developed" region (Australia, New Zealand, South Africa). In developing regions, and especially West Asia—North Africa, the opposite rule prevails, i.e., a shift towards more energy-intensive commodities. The fast industrialization process in new industrializing areas is also driving many developing economies toward energy-intensive components of sub-sectors.

The overall change in energy intensity by region is computed as the sum total of the output-mix and the technological progress effects. The former is a weighted average (with constant dollar production figures as weights) of the output mix effect by industry, as obtained in the preceding chapter, while the latter is a weighted average of assumed technical progress trends by industry. Considering firstly the technical progress component, it is no wonder that annual rates are found very close from one region to another, around −2.2%, since exogenously assumed industry trends do not differ widely. More interesting appears the series of output-mix effects. The range of trends due to structural change (in percent p.a.) is −0.5 to .7 in the first four developing regions, all negative, while no significant trend was found in the "Other Developed" region, the most natural-resource endowed in basic products. In contrast, three positive trends were found in Latin America, Sub-Saharan Africa and West Asia—North Africa, with the following values (in percent p.a.): 0.5, 1.9, and 1.3, respectively. Finally, two negative trends emerge for the Indian Sub-Continent (−0.4%) and for East and South-East Asia (−1.7%). The latter figure should be interpreted with caution since it is largely due to one sub-sector, chemical industry, with a decreasing weight, not to mention the uncertainty in estimating a trend in this sub-sector. Adding up the two components, decreasing trends in energy-intensity ranging from −2.1 to −2.9%, emerge in developed regions, with a diversified picture in developing regions: no overall trend in Sub-Saharan Africa, where the increasing intensity due to structural change compensates the decreasing intensity due to technical progress, a negative −1% trend in West Asia–North Africa, negative trends around −2% in Latin America and the Indian Sub-Continent, and a controversial figure close to −4% in East and South-East Asia.

The least that can be said on the structural change effect is that the positive changes found in Latin America, Sub-Saharan Africa, and West Asia–North Africa comply with expectations since these regions are natural resources and/or energy endowed. The negative trends found in the four largest developed regions, on the other hand, extend and confirm the analysis made in Chapter I.3, i.e., a proportion close to 25% can be attributed to structural change in the overall decrease in energy intensity. Finally, the negative results for the last two developing countries, the Indian Sub-Continent and East and South-East Asia, are more fragile, since it appears from the analysis in Chapters I.5 and I.6 that an increase in energy intensity is observed in a number of sub-sectors. The negative trend of the structural change effect observed in the 1970–1981 period may therefore be reversed in the future as a result of a continuation of the industrialization policy in these areas.

It therefore looks as if major changes occurred in the 1970s in the international division of labor of primary processing industries: developed countries moved towards less energy-intensive industries, while an increased share of more energy-intensive industries was observed in developing regions. Even though it is too early to state that these changes can be considered as long-term trends, it is interesting to study, through simulations, to what extent they are likely to affect the world energy balance. This is the object of Part II.

Part II.

This part deals with forward-looking explorations of energy issues based on the analysis achieved so far. It is divided into four chapters, the first briefly mentions relevant methodological aspects of the UNITAD model, which is a UNIDO model built up for long-term exploration purposes. The second follows directly from Part I and concentrates on energy issues. The macroeconomic framework is then justified and analyzed in the medium-term (1984–1990) in Chapter II.3 and in the long-term (1990–2000) in Chapter II.4. Brief policy conclusions follow.

In order to carry out forward-looking simulations, the data base of the UNITAD model was enlarged to incorporate relevant data of the world economy. As a starting point, input/output coefficients were updated to 1970, using both energy-saving coefficients derived from the historical analysis (Chapter I.6) and a new set of 1980 input-output tables supplied by UNIDO for all regions. The model was also adjusted to give energy balances in physical units (million tons of oil equivalent, mtoe). In order to do this, it was necessary to establish transition figures between constant price data in the model (expressed in 1970 prices) and primary energy units (expressed in tons of oil equivalent (toe)). This was done for each of the four energy sub-sectors of the model. These adjustments are briefly reported in Chapter II.1.

The potential impact of conclusions derived from Part I on world energy balances is considered in Chapter II.2. Simulations were designed so as to allow only one shock to the system at one time and to do this, it was considered preferable to operate on the period extending from 1990 to 2000 rather than in the 80's where conditions are likely to be influenced by many events. Following a base-line scenario from 1980 to 1990 (described later), three different simulations (denominated A,B,C) were built up for a ten-year period. Simulation A is based on an assumption that no permanent structural changes towards less energy-intensive industries take place in the Basic Products sector of developed countries. So energy input coefficients in developed countries were modified by a multiplyer reflecting only the continuation of trends in technological progress. No such trends were applied, by convention, to the Basic Product sector of developing regions in this and other simulations. In simulation B, two sets of exogenous assumptions were introduced: On the industrial side, developed countries specialize in less intensive processing industries (input coefficients are affected by a multiplyer reflecting both the technological progress trends and the output-mix effect described in Chapter I.6); on the trade side, an international division of labor progressively develops in all manufacturing goods: developing regions sell more intermediary products (produced in the Basic Products sector) both to developed countries and on their own markets; other commodity markets also benefit by trade liberalization but to a minor extent as compared to intermediary products. In this experiment, all other parameters, and in particular GDP growth, were kept at the same level as in simulation A, so as to derive the primary order effects of the assumptions. Finally in simulation C, a 1-percentage point of annual growth rate was added up in all developing regions, in order to derive marginal growth elasticities for comparison purposes.

The result of the experiments firstly confirm expectations: when considering the industrial uses of energy, total primary units consumed in the South increase in simulation B, compared to A, while the opposite is observed in developed regions. But one interesting result emerges: the total world primary use of energy in industrial sectors decreases, and so does total world energy consumption; this reflects the fact that all indirect effects of the North–South substitution in the Basic Products sector, when permeating other sectors of developing economies, give rise to less energy consumption than in the North (e.g., income accruing to households is spent in much smaller energy per capita figures).

Another major implication is the shift in the world structure of the basic products sector, and of manufacturing at large. For developing economies as a whole, the Basic Products sector grows with an elasticity relative to GDP of 1.4 in simulation B, as against 1.3 in simulation A (for comparison purposes, the marginal GDP growth elasticity of the sector in simulation C is only 0.95). The manufacturing sector as a whole is also boosted in developing regions, with GDP growth elasticities of 1.3 in simulation B compared to 1.2 in A. As a consequence, the Value-Added of manufacturing in market developing regions over the world total would rise from 9% in year 1990 (14% with CPE, Asia) to 14% of world total (20% if CPE, Asia is included) in simulation B, as against 13% in simulation A (19% with CPE, Asia).

These results can be traced up to the assumptions made on trade liberalization and other aspects of the world economy. Among these aspects, one may quote:

- the exogenous assumptions on the GDP growth rate of the North (around 3% p.a.),
- the low trends in energy prices, as described in the IIASA document in Annex 4,
- and finally, the financial and monetary rules governing the level of indebtedness in developing regions of the South: long-term interest rates in financial markets are supposed to be in the 7–8% range in the 1980's and 2–3% in the 90's (in real terms).

The trend scenario up to 1990 and simulation A from 1990 to 2000 can be considered as a base-line scenario up to 2000, with simulation B as a variant. The major macroeconomic implications of these assumptions are described separately for the medium-term future (up to 1990) and for the longer term (1990–2000).

In the medium-term (Chapter II.3), a no-change policy line was adopted for the major international parameters reviewed above. The 2.9% p.a. assumed for developed market economies, matched with a severe debt management, i.e., a zero growth of debt in real terms, yields a rather gloomy picture of the world economy in 1990. In the North, there is no hope to achieve a full-employment target, and developing countries would be even farther away from their performances in the 70's (5.3 % p.a.), with a 4.1 annual growth rate for the 1984–1990 period. The growth pattern is strongly influenced by the debt burden. Growth rates in Asia are acceptable while they are poor in Latin America, with a 3.1% p.a. growth rate, and miserable in Sub-Saharan Africa (0.9%). Altogether, in the 1980–90 decade, per capita growth rates decline in Latin America and Sub-Saharan Africa.

These figures illustrate the likely medium-term implications of the type of low-growth equilibrium generated by the present environment: massive unemployment in the North, no solution to the debt problem of the South, and frustrating social situations in two continents. Alternative solutions, so desperately needed, are explored in the 1990–2000 scenario.

Two sets of assumptions govern the base-line 1990–2000 scenario (formerly denominated simulation A) as described in Chapter II.4. Hardly any change are made on the annual growth rate of the North (3.1%) as compared with the medium-term scenario. This was deliberately chosen, among possible alternative assumptions, if only to demonstrate that a different world equilibrium could be attained with cautious assumptions on developed economies. In addition, a systematic attempt was made to alleviate the debt burden: firstly, on the financial side, real interest rates were kept low (2–3%); secondly, developed market economies liberalized trade so as to enable developing economies to export more and to repay part of their debt. This means that developed countries would accept "structural" deficits in their trade balance with the South over the decade, with very little feedback effect of the growth of South on the North. Arbitrary though these assumptions look like, they illustrate an extreme policy line which is meant to be useful for comparison purposes.

The growth effect of these assumptions on the South is spectacular, since their annual growth rate reaches 6.9%, almost the target set forth in the UN development decade. In particular, Latin America achieves a 7.8% growth rate, and Africa 4.2%. The explanation lies in the success of export performances for manufactures where developing regions double up their world share over the decade (above 20% compared to 10% in 1990). Out of this share, East Asia alone makes more than 50% total manufactures exports of the South, and Latin America, another 28%. Intermediary products, in manufactures exports, becomes the first commodity group (around one third), followed by equipment and machinery (30%). These results can be taken as illustrating the trade aspect of the international division of labor described in Chapter II.2.

Conclusions

Two major policy conclusions emerge from these simulations. On the macroeconomic policy side, this study illustrates one possibility of achieving a much better world equilibrium than is likely to result from the continuation of present trends. With a more liberal management of world trade – even allowing for a long adjustment period for the North – and a political will to solve the indebtedness problem, much higher growth rates can be achieved in developing areas and (although it was not explored here) in developed countries.

On the energy side, as considered in this study, such higher growth of the world economy would permit a fast development of energy and capital intensive industries in the South belonging to what is called here the basic products or the primary processing sector. This development, it was shown, which conform to a rational international division of labor in the energy-endowed South, would comply with reasonable assumptions on the likely development of the energy sector. At any rate, the high growth of energy consumption in the South resulting from the development of the primary processing sector would altogether alleviate world demand pressure for energy (and therefore lower energy prices) as compared with a continuation of the present concentration of the industry in the North.

To sum up, industrial redeployment in the primary processing industry not only tends to achieve a better South–North balance of the manufacturing sector along policy lines advocated by UNIDO, but it would also contribute to an optimal use of scarce energy resources at the world level.

PART I: HISTORICAL ANALYSIS OF ENERGY COEFFICIENTS

I.1 SURVEY OF STUDIES AT THE INDUSTRY BRANCH LEVEL

The long-term forecasting of energy demand is usually based on a functional relationship between energy consumption and economic activity. Therefore, the energy/output ratio and the elasticity of energy use with respect to output play a central role in energy-demand analysis, and therefore they have been widely discussed and estimated. Past studies for developing countries* have shown, in general, elasticities significantly larger than 1. For developed countries there have been a large number of studies, sometimes with seemingly contradictory results. Time-series studies by Nordhaus (1977) and Kouris (1976) found elasticities for advanced economies of around 0.8, but not significantly less than 1. Kouris (1976) demonstrated decreasing elasticities in the fifties, followed by a gradual increase towards unity. On the other hand, Brooke (1972) presented a cross-sectional analysis covering countries representing a wide range of development levels, which showed elasticities tending towards 1 from above. If changes in energy efficiency caused by differing fuel mixes are excluded, Brooke (1972) found elasticities for advanced economies of around 1 and for developing countries of around 1.5.**

It is observed in general that in the early stages of development, when an economy is moving towards industrialization, energy substitutes other production factors (particularly labor) and the share of energy-intensive basic products (basic metals, building materials) increases rapidly; this is reflected by a large elasticity of energy use.

It is also observed that for developed countries there is a tendency to reduce the energy/output ratio so that elasticities will tend towards 1 from below.

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* Zilberfarb and Adams (1981) found elasticities of approximately 1.4.

** As a part of efficiency growth is excluded in Brooke's analysis, his elasticities may be slightly overestimated compared with unadjusted figures.

For the industrial sector energy-demand patterns are determined by the mode and structure of production, or more precisely by:

- the technology used, and
- the product mix of industrial output.

This section summarizes the results of a few studies that will help to quantify the impact of structural changes on differing energy demand patterns. An attempt will be made to subdivide pure technology effects from effects that are due to changing production structures.

Doblin (1983) analyzes the reasons for the changing energy/output ratios for the USA, the FRG, the UK, and France over the period 1970–1981; Table 1 shows a more or less constant decline in energy/output ratios. On the other hand, growing industrial activity (except for the short breaks in 1974/75 and 1980/81) can be recognized for most of the countries concerned together with increasing industrial outputs, and decreasing energy/output ratios imply elasticities of less than 1. It may be argued that this pattern is characteristic of post-industrialized economies. A further glance at the composition of industrial outputs (Figure 1) leads to the assumption that, over the long term, the industrial sector's demand for energy was cut back because of changes in output profiles. While total industrial production has risen, the most energy-intensive branches have declined or remained at the level of 1970. It is remarkable that the gap between the most energy-intensive production activities and total output grew increasingly after both oil shocks. This may encourage the assumption that, at least in the short run, the response of industrial management and policy makers to the rise in energy prices was not to increase efficiency but rather to substitute energy-intensive and therefore increasingly expensive products by other materials, and simply to decrease the share of energy-intensive inputs (e.g. machinery and transport equipment became more light and fragile). Another remarkable result is that there is a negative correlation between the energy intensity of production and the value added content of output. In 1970, the six most energy-intensive industries, which accounted for nearly 80% of industrial energy demand in the USA, contributed only 33% to the value added of the manufacturing sector as a whole. While in the seventies the growth of these energy-intensive basic industries was progressively slower, the high-technology value-added-intensive sectors, such as electrical engineering and pharmaceuticals, grew rapidly. Therefore Doblin (1983) concludes, "all the time the breaking of the energy coefficient was a myth... sustained cutbacks in total primary energy consumption originate from the structural change of industries

Table 1. Energy consumption and total industrial production (both as index numbers, 1970 = 100) in the United States, France, the FRG, and the UK, 1970–1981.

Year	Energy consumption (all fuels and electricity) (E)	Total industrial production (x)	Energy output ratio ($E/x \times 100$)	Energy consumption (all fuels and electricity) (E)	Total industrial production (n)	Energy output ratio ($E/x \times 100$)
	United States			*France*		
1970	100.0	100.0	100.0	100.0	100.0	100.0
1971	–	100.1		–	106.0	
1972	–	108.0		106.2	111.0	95.7
1973	106.7	117.7	90.7	113.0	120.0	94.2
1974	102.6	117.0	87.7	119.4	123.0	97.1
1975	93.3	110.4	84.5	109.8	115.0	95.5
1976	98.7	121.6	81.2	109.9	124.0	88.6
1977	100.4	128.5	78.1	111.8	126.0	88.7
1978	101.3	136.9	74.0	113.0	129.0	87.6
1979	103.7	142.9	72.6	117.1	135.0	86.7
1980	96.2	137.9	69.8	114.7	133.0	86.2
1981	89.9	141.5	63.5	109.8	130.0	84.5
	FRG			*UK*		
1970	100.0	100.0	100.0	100.0	100.0	100.0
1971	97.1	101.0	96.1	97.5	100.0	97.5
1972	98.7	105.8	93.3	98.3	102.0	96.3
1973	105.3	112.7	93.4	104.5	111.0	94.1
1974	105.4	110.7	95.2	96.4	108.0	89.3
1975	92.5	104.6	88.4	88.9	102.0	87.2
1976	97.2	112.7	86.2	92.5	104.0	88.9
1977	97.0	115.0	84.3	92.4	108.0	85.6
1978	97.6	117.0	83.4	90.9	112.1	81.1
1979	101.4	123.1	82.4	94.0	114.3	81.9
1980	97.0	123.1	78.8	77.6	107.4	72.3
1981	92.6	120.6	76.8	73.3	101.9	71.9

Source: Doblin (1982).

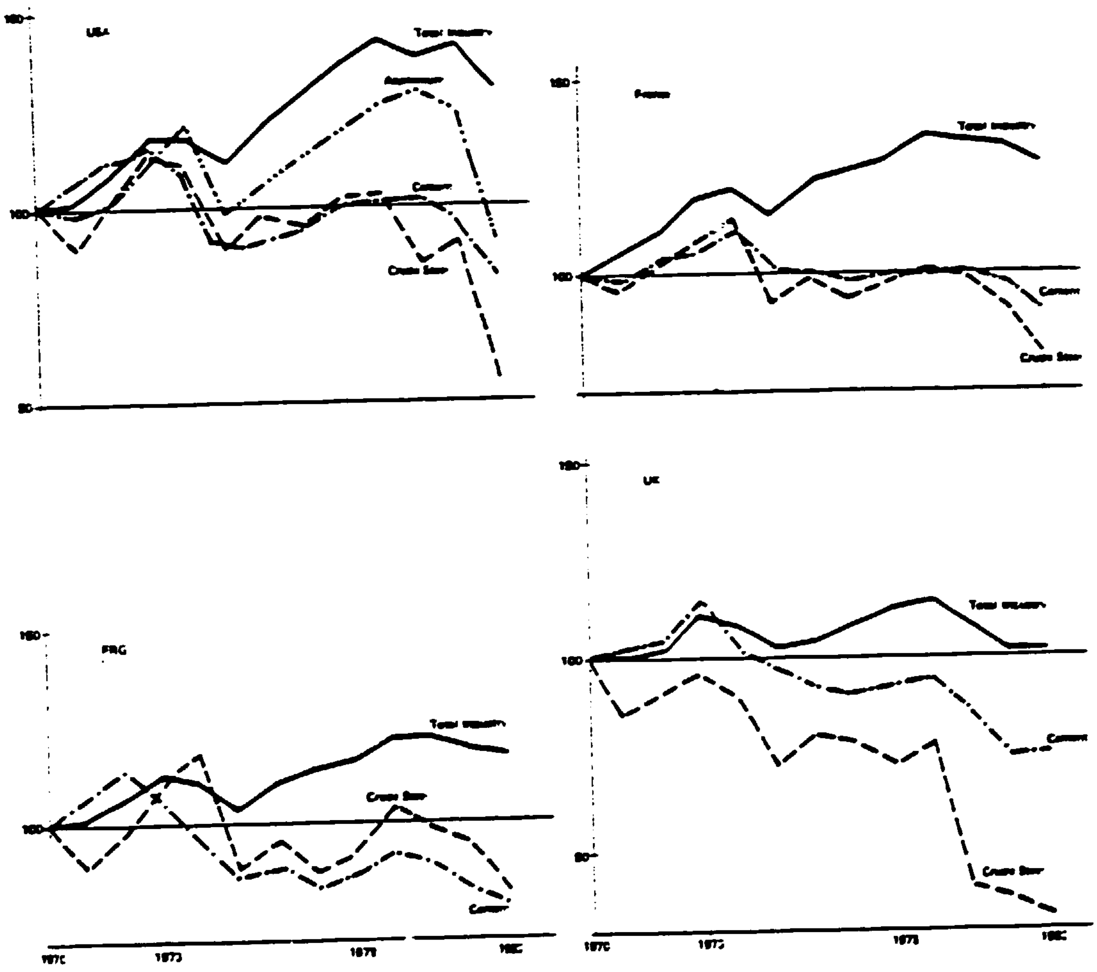

Figure 1. Growth of total and selected industries, 1970–1982, index numbers (1970=100). Source: Doblin (1983).

and of the economy."

Very similar figures can be observed for the Japanese economy. While Japanese GNP and output of the manufacturing sector as a whole in Japan went up, despite a short decline after the first oil crisis, energy consumption in manufacturing industries has decreased (Figure 2). Figure 3 leads again to the conclusion that changing production structures have an enormous effect on the energy/output ratio. Sagawa (1984) subdivided the shifts in Japanese industrial energy use into four parts:

- changes due to increases in efficiency of energy use, including unidentified changes in the production structure of identified industrial branches (intra-industrial product-mix effects):
- changes due to a shift towards high-value-added products within industries (which may indicate hidden intra-industrial product-mix effects);
- changes due to interindustrial output-mix effects expressed as changes in the weights of value added among industries; and finally
- changes due to growth of real GDP (changes in the level of economic activity).

The results of this decomposition are shown in Figure 4. Most of the decline in the aggregate energy/output ratio of the Japanese economy can be attributed to shifts towards high-value-added products and energy saving. Taking into account the fact that a large and increasing part of "energy conservation" is due to unidentified intra-industrial product-mix effects, expressed as changes in the value-added coefficients, it is obvious that the effect of pure energy saving is overestimated. The chief reason for stagnation of energy demand per unit of industrial output can safely be attributed to changing intra- and inter-industrial output structures.

With the help of input—output analysis, Ploger (1983) shows that, besides GDP-level effects, the main part of the reduced energy consumption in Danish industries has been brought about by changes in the energy coefficients and by changes in import shares. While the growth in Danish GDP over the period 1966—79 caused an increase of 268,000 TJ or 79% in energy consumption, changing import shares were responsible for a decrease of 16%, changing energy coefficients for a decrease of 17%, and the changing composition of final demand for a decrease of 4%, so that the actual overall energy consumption of Danish industry increased by only 42%.

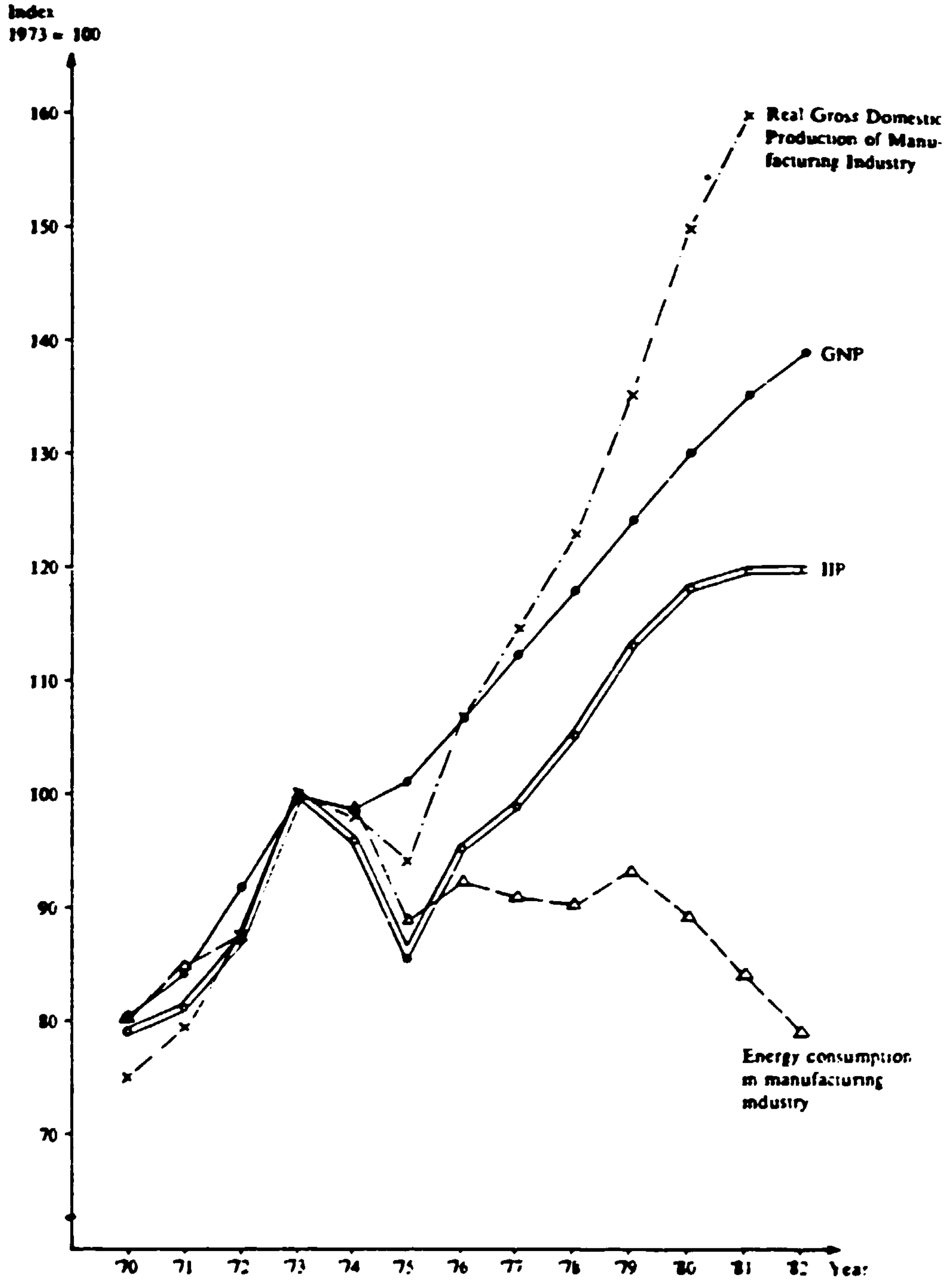

Figure 2. Energy demand in manufacturing industry and economic indexes (1973 = 100). Source: Sagawa (1984).

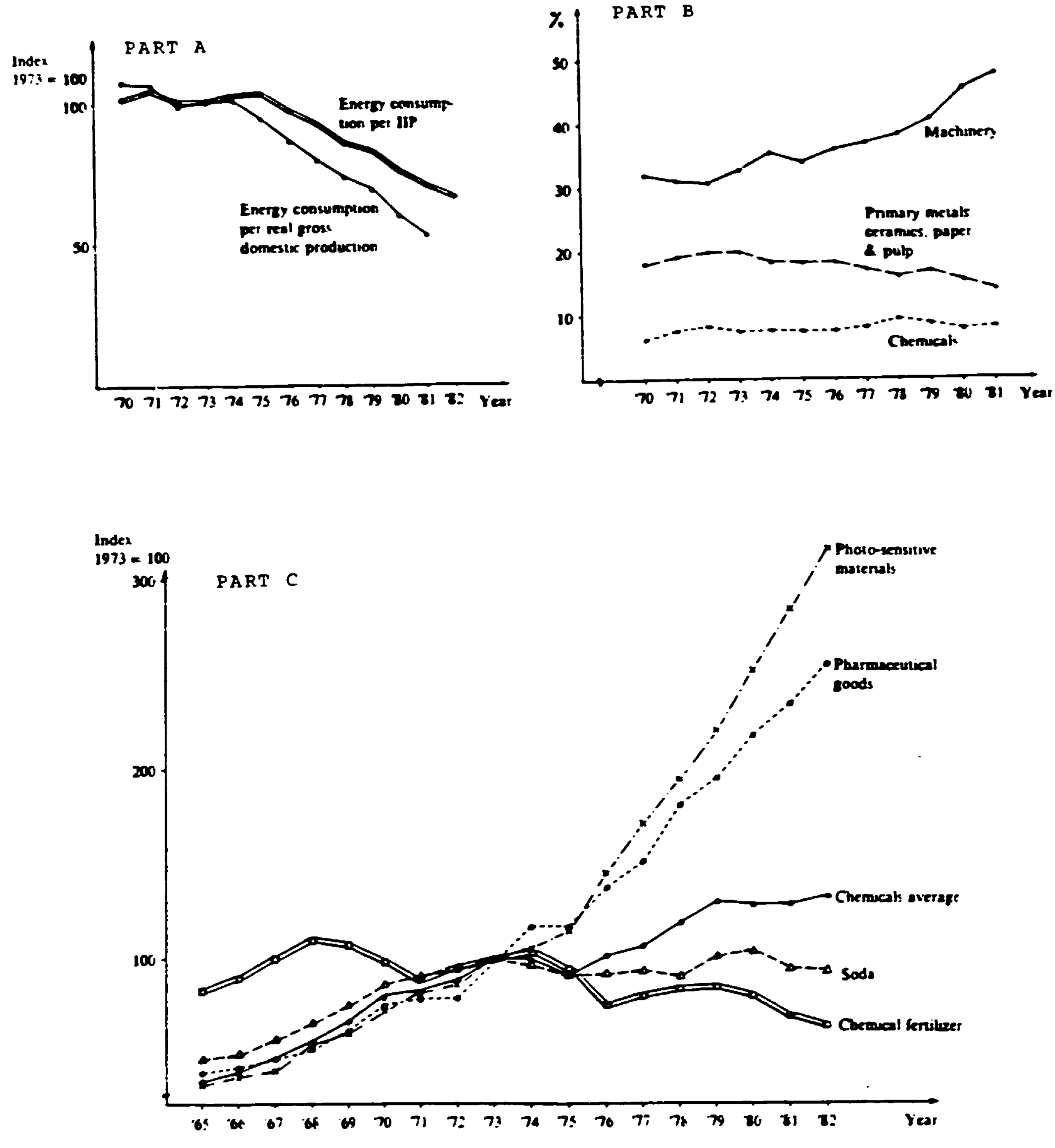

Figure 3. A: Trends of energy consumption per production unit in manufacturing industry; B: Trends of shares of real gross domestic production of each industry in the total of manufacturing industry; C: Trends of production index by item in the chemical industry. Source: Sagawa (1984).

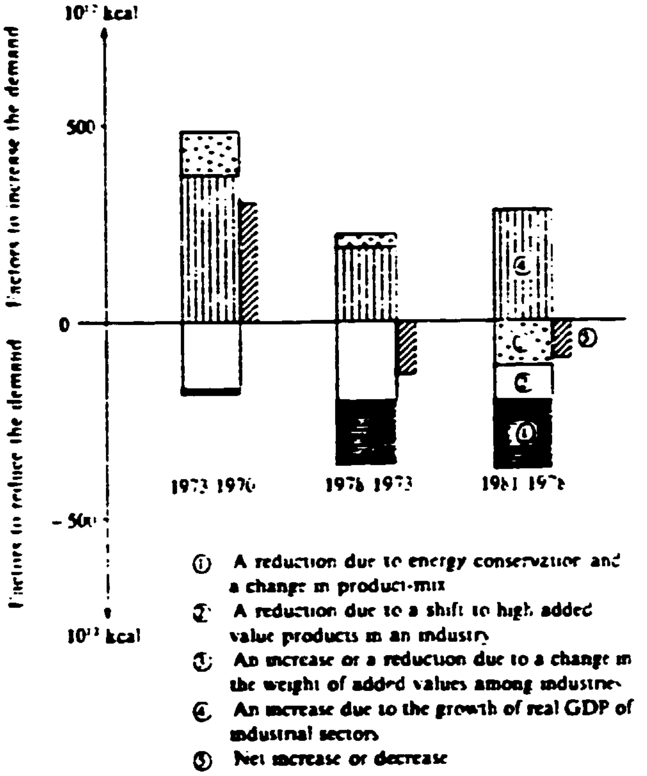

Figure 4. Factors that induce changes in energy demand in industrial sectors. Source: Sagawa (1984).

For the Austrian economy Bayer (1982) discovered that energy-saving effects represented by changes in industrial energy/output ratio were much higher *prior to* the first oil shock in 1973. While the decline in energy/output ratios during the sixties was mainly caused by interfuel substitution (changes from coal to more efficient oil and gas technologies), the major part of the decrease in the energy/output ratio associated with the first oil shock was due to shifts from energy-intensive basic sectors towards the final production branches of the manufacturing sector.

For the French economy, Martin, Chateau, Criqui, Lapillonne (1984) acknowledge the changes in the pattern of energy consumption after 1973 observed in all major industrialized countries, and the decrease of the energy content of growth, making a distinction according to industries between the content and structure effects.

Marlay (1984) studies the US industry's energy consumption and attributes the reduction of consumption compared to past trends to improvements in the efficiency of industrial process technologies, slower industrial growth and changes in the composition of industrial output, i.e., a move away from energy-intensive activities.

For international comparisons, Sagawa and Kibune (1984) notice that differences in levels of energy/GNP elasticities depend on the level of development as well as on the geographical position. Chateau and Lapillonne (1982) relate energy consumption to socioeconomic variables, and note that the structure of economic activities directly determines the energy demand, and that the future development of tertiary activities will imply a growth of energy consumption slower than that of activity.

The changes in processes in some energy-intensive industries are studied by Burwell (1982, 1983, 1984). For pulp and paper, one can isolate some factors of decrease of the energy consumption such as the use of waste paper instead of pulp, or the resort to imported pulp. New techniques in paper industry go towards a better use of water (less water needed and a better efficiency in evaporation). For the glass industry the reuse of glass is a factor of energy savings, just as the improvement of furnaces and insulation. In the steel industry, Burwell notes that the generalization of the electric process and reuse of scrap is a major factor of increasing energy efficiency. The ECE (1983) adds to these factors the shift away from the Open Hearth process to the more efficient Basic Oxygen process, and the increasing share of continuous casting. The OECD study (1983) on aluminum industries stresses the particular energy-intensiveness of this industry. The crisis that this industry experiences is a strong factor of structural changes, such as the worldwide reallocation according to electricity prices and the important shutdowns of plants. No major changes in processes has occurred, there is a general improvement of the technologies used, and a trend towards a larger reuse of scrap. The growing importance of electric melting is higher than that of fuels. As is mentioned in Burwell (1983), oxygen enrichment in the smelting of copper reduces the total use for energy.

This section has suggested that a large proportion of the decline in energy/output ratios can be attributed to changes in the structure of industrial production. In the next section a model will be elaborated that permits a more detailed explanation of the effects of structural changes on energy/output ratios.

I.2 ECONOMETRIC MODELING OF PRODUCT-MIX AND PRICE EFFECT ON THE ENERGY SAVINGS: A CASE STUDY FOR AUSTRIA

From the previous overview it becomes clear that most studies dealing with analyses of energy demand by industry (or by a subindustry) tend to introduce and analyze the energy output ratio without an attempt to split the effects of structural change and the energy-saving technological progress in the energy coefficient. Even if a sectoral (commodity) breakdown is performed, most studies remain restricted to fixed energy/output ratios at a disaggregated level. We see the reasons for this either in the lack of data or in the data inconsistency which limits the analysis to pure algebra multiplying fixed energy intensities by structural changes or staying at the aggregated level. Clearly time series of energy input are mostly available at the level of aggregated industrial branches.

In this section we present results of an attempt to analyze both changes in the structure of the most energy-intensive industries at the commodity level taking into account the possible impact of an energy price change in the energy saving technological progress at the micro level. This must be considered as an attempt to bring econometric techniques to a set of data which, in general, are complementary, and by doing so, to derive some conclusions on the possible impact of technological progress on the aggregated energy/output ratio.

The following data for Austria (usually available for a majority of developed countries) and notations* are used:

$E(t)$ Energy input into an industry (which is considered as a subject of analysis, aggregated) is measured in comparable physical units (Joules, coal or oil equivalent); these data are – at least for aggregated industries – supplied by national censuses or complied by international organizations (IEA/OECD);

$X(t)$ Gross output of an industry (value of sales or shipments) in constant prices – for many countries these data are also available.

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* In general these notations are used in the later sections of this report.

$Q_i(t)$ Commodity outputs for selected energy-intensive products measured in physical terms. These data are usually reported by national statistical offices and compiled by UN (1981).

$e_i(t)$ Energy inputs per unit of volume of an i-th commodity, so-called engineering data. These data are rarely reported on a comparable basis and are usually taken for some benchmark years from a variety of sources – some of them contradict each other. However, some ranges of these coefficients can be found, at least for recent years (see Boustead-Hancock 1979).

If and only if all the data required cover the industry performance, there is no difficulty to compare the results of the aggregation by commodities with the reported aggregated figures, i.e., the equality must at least be roughly fulfilled:

$$E(t) \simeq \sum e_i(t) \cdot Q_i(t) \qquad (1)$$

Of course it will be equally dangerous to assume $e_i(t)$ fixed over time or to look only into aggregates if the development of different products is not the same. Being concerned with available data firstly on $e_i(t)$ we assume

$$e_i(t) = \tilde{e}_i \cdot P(t)^{\beta} \qquad (2)$$

where

$P(t)$ – price index for energy used by the industry*

β – price elasticity of energy use with respect to the industry concerned. (Again β might differ from product to product, but it makes it difficult to assume different β_i while no information on energy carriers is used)

$\tilde{e}_i$ – energy intensity in the base year taken from engineering data.

In the case of Austria energy use, in both physical units and in millions of current Austrian Schillings (AS), was supplied by an establishment-based census of Austrian industrial firms, so that we may derive the required time series of prices by dividing these two sets of figures. To avoid the problem of the overestimation of a model quality in terms of goodness of fit we work with relative figures, i.e., the

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* Of course, if an information on the energy carriers' structure is given for different commodities, one may specify $P_i(t)$, but further on we take it for the selected industry as it is. Thus price indexes (1971=100) were calculated by dividing the total energy costs of the industries concerned at current prices by total energy use values in terajoules (TJ) and normalizing the price series.

equality (1) is rewritten in terms of:

$$e(t) \simeq \sum e_i(t) \cdot c_i(t) \tag{3}$$

where $c_i(t)$ is the share of the i-th commodity in the industry output and $e(t)$ is the energy intensity of the whole industry. It can be done if corresponding outputs by commodities are reported in constant prices or by deriving the required values under the assumption that prices by commodities are known and commodities are rather homogeneous so that

$$x_i(t) = \bar{P}_i Q_i(t)$$

where $\bar{P}_i$ is a base year price of a unit of the i-th commodity.*

Taking into account possible drawbacks when estimating a model with a limited number of commodities, we came to a regression:

$$e(t) = P(t)^{\beta} \cdot \sum \tilde{e}_i \cdot c_i(t) + \varepsilon(t) \tag{4}$$

where $\varepsilon(t)$ is an error term or a variable which might absorb all effects of the model inaccuracy.**

Here the following advantages of the approach are clear – structural changes within an industry are considered in terms of c_i, engineering estimates for energy input per commodities are used in terms of $\tilde{e}_i$, price influence is also taken.

Table 2 shows the estimated energy coefficients and the price elasticities (estimated with model (4)) for the five industries studied. The standard errors of the base-year coefficients ($\tilde{e}_i$) for all of the energy-intensive products appear very low, indicating the high explanatory power of the product-mix coefficients of the most energy-intensive products in each industry. Estimates for other, less energy-intensive products are mostly insignificant. Most of the price elasticities (except for the food and beverage industry) are also significant but the t-statistics may indicate in general that prices have less explanatory power than the product mix of energy-intensive commodities.

To evaluate the present approach compared with more traditional methods, price elasticities were estimated without taking product-mix effects into account, i.e., by estimating a macro model:

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* For the most energy-intensive commodities it may work well. In this case study all values are expressed in 1971 prices in Austrian Schillings.

** The ordinary assumption will be $\varepsilon(t)$ is a random normally distributed error term.

Table 2. Estimates of model (4) for five vectors

Industry	Commodity	Energy coefficient e_i		Price elasticity[a], β		R^2
Nonmetallic mineral products	Cement and lime	11.9	(4.0)	−0.21	(0.09)	0.997
	Rest of output, incl. bricks	0.13	(1.8)			
Pulp, paper	Pulp	4.1	(0.36)	−0.14	(0.03)	0.999
	Paper	1.8	(0.16)			
Nonferrous metals	Nonferrous metals (electrolytic)	3.15	(0.25)	−0.31	(0.12)	0.997
	Other output	0.05	(0.16)			
Chemicals	Fertilizers, rubber products, basic chemicals	3.08	(1.01)	−0.85	(0.28)	0.980
	Rest of output	0.60	(0.65)			
Food, beverages, tobacco	Sugar, beer	2.29	(0.41)	−0.03	(0.06)	0.998
	Rest of output	0.06	(0.09)			

[a] Standard errors in parentheses.

$$e(t) = \tilde{e} \cdot P(t)^{\beta} \ , \tag{5}$$

where $\tilde{e}$ is an aggregated energy intensity in the base year.

Table 3 compares price elasticities calculated according to eqns. (4) and (1), respectively. A graphical display of fitted vs. actual values (Figures 5 and 6) illustrates the explanatory power of the model (4); price effects calculated according to eqn. (5) are also shown.

The introduction of product-mix effects into the estimation procedure produces a decline in price elasticities of between 8 and 48%, a remarkable decline in t-values, and an increase in R^2-values. This has the following implications:

- The hypothesis that changes in the output structure of an industry seriously affect input coefficients is confirmed.
- Price changes affect input structures. But if product-mix effects are introduced, the price elasticity of energy demand becomes smaller and the explanatory power of prices declines. The microtechnologies (on the commodity level) are less energy elastic than the macrotechnologies (on the industry level).

Table 3. Estimates of models (4) and (2) for five sectors.

Industry	Price elasticities[a]					
	With product mix, β		R^2	Without product mix, $\bar{\beta}$		R^2
Nonmetallic mineral products	−0.21	(0.09)	0.997	−0.35	(0.04)	0.867
Chemicals	−0.85	(0.28)	0.980	−0.95	(0.11)	0.835
Paper	−0.14	(0.03)	0.999	−0.22	(0.03)	0.830
Food, beverages, tobacco	−0.03	(0.06)	0.998	−0.21	(0.04)	0.630
Nonferrous metals	−0.31	(0.12)	0.997	−0.79	(0.17)	0.606

[a] Standard errors in parentheses.

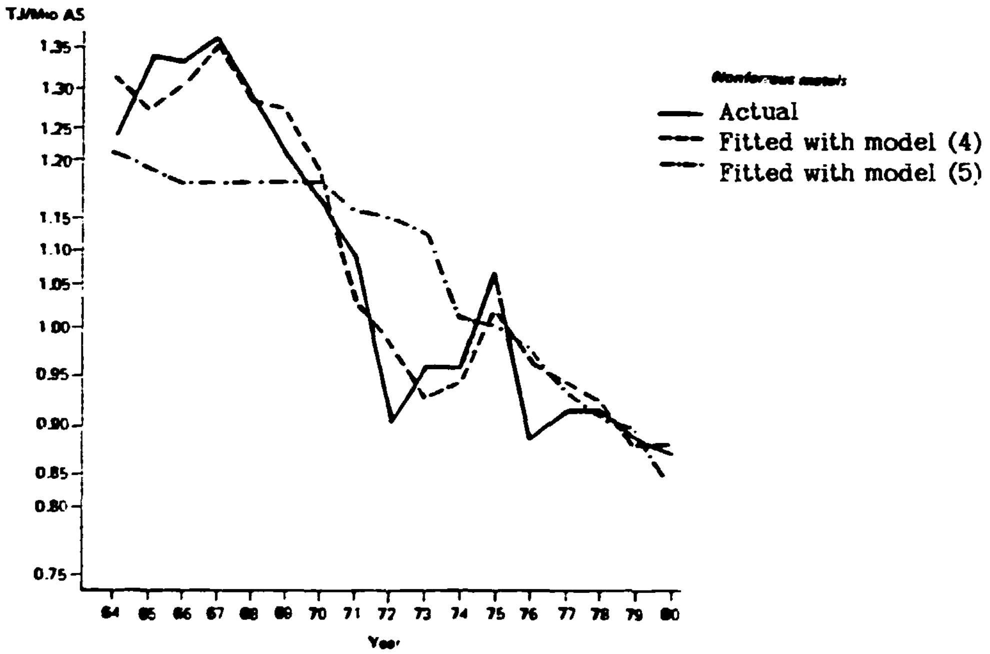

Figure 5. Actual and fitted paths of the energy coefficient for the nonferrous metals industry. Source: Lager (1983).

- From this, it follows that price changes do not only affect input structure but also have an influence on the output profiles of industries.

One of the restrictions of the whole analysis is that the data supply is – even on an industry level – limited. In order to see how a less data-intensive approach (without taking prices into account) works, the same data were then applied to model (6), in which it is assumed that technical progress improves the energy efficiency of the industry concerned at a constant instantaneous rate λ

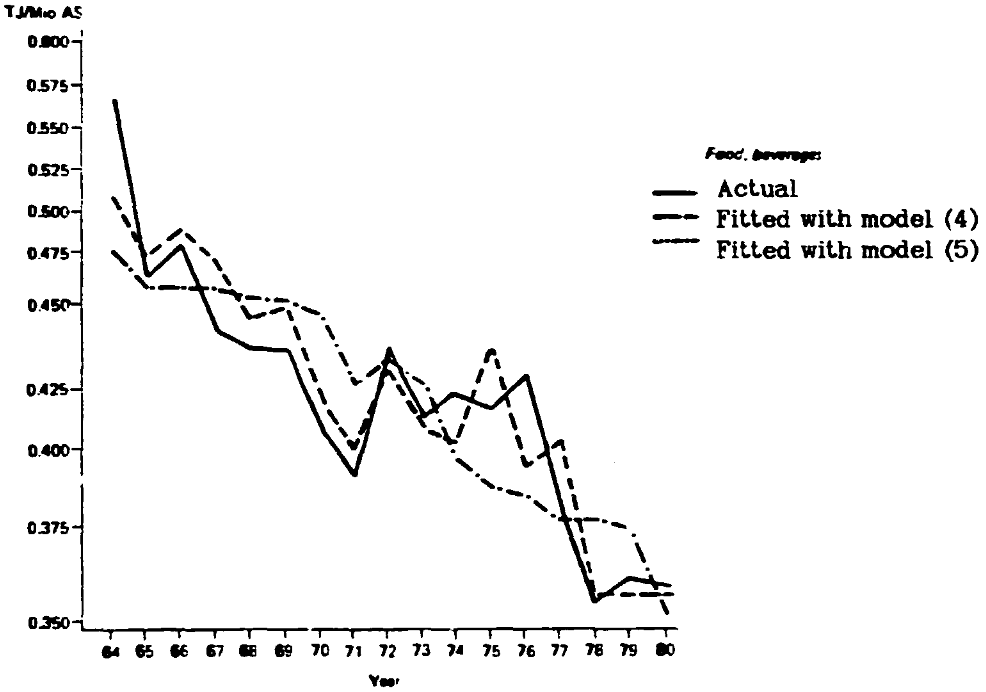

Figure 6. Actual and predicted paths of the energy coefficient for the food and beverages industry. Source: Lager (1983).

$$e(t) = \exp(\lambda \cdot t) \cdot \sum \tilde{e}_i \cdot c_i(t) + \varepsilon(t) \qquad (6)$$

Table 4 shows the estimates of the energy coefficients for the base year and the rates of energy savings.

The very high R^2 indicates the goodness of fit of the regression. The t-statistics again indicate a high explanatory power of changing output structures. The growth rates are in general very small except for the growth rates in the chemical industries. The estimated role of technical progress in the food, beverage and tobacco industry is insignificant.

Table 5 compares the estimated energy coefficients ($\tilde{e}_i$) from both models (4) and (6) with available engineering data, which were found expressed in gigajoule per ton and were revalued using prices (million AS/1000 tons) to obtain a comparable TJ/million As basis. The comparison demonstrates that most of the estimated coefficients lie within technologically measurable bounds.

The exercise and the findings on the Austrian data lead to the following conclusions which have implications on the further procedure and extension of the analysis:

Table 4. Estimates of model (6) for five sectors.

Industry	Commodity	Energy coefficient[a] ($\tilde{e}_t$)		Rate of energy saving[a] (λ)		R^2
Paper	Pulp	3.38	(0.29)	−0.015	(0.002)	0.999
	Paper	2.46	(0.16)			
Food, beverages, tobacco	Sugar, beer	2.16	(0.48)	−0.004	(0.006)	0.998
	Other output	0.09	(0.12)			
Nonferrous metals	Nonferrous metals (electrolytic)	2.96	(0.32)	−0.013	(0.005)	0.998
	Other output	0.27	(0.24)			
Nonmetallic mineral products	Cement, lime	9.09	(2.18)	−0.025	(0.003)	0.999
	Other output	2.09	(1.08)			
Chemicals	Basic chemicals, fertilizers, rubber products,	3.35	(0.52)	−0.067	(0.006)	0.996
	Other output	1.26	(0.39)			

[a] Standard errors in parentheses.

- The price model (4) has no more explanatory power than the trend model (6).
- Both models (4) and (6) which take product-mix into account explain the changes of the energy/output ratio better than a pure price-elasticity model (5).
- Energy intensities estimated by regression techniques are close to intensities taken from engineering studies.

This encourages the general conclusion that a simple model with time trend and explicit treatment of the product-mix effect (model 6) is a reasonable tool to explain the changes of the energy/output ratios in the most energy-intensive branches; instead of estimating micro-energy intensities, engineering data can be used.

Table 5. Comparison of estimated coefficients with engineering data (both in TJ/million AS).

Commodity	Estimated energy coefficients[a]				Engineering data[1)]
	Model 4		Model 6		
Pulp	4.1	(11.4)	3.4	(11.7)	3.0–4.3
Paper	1.9	(11.3)	2.5	(15.4)	0.5–2.7
Cement	11.9	(3.0)	9.1	(4.2)	8.4–12.5
Lime					9.6–11.7
Aluminum (electrolytic)	3.2	(12.6)	3.0	(9.3)	5.1–6.3
Other metals (electrolytic)					1.0–1.6
Sugar	2.3	(5.6)	2.2	(4.5)	2.3
Beer			9.8		
Basic chemicals	3.1	(3.0)	3.4	(6.4)	

[a] *t*-statistics in parentheses.

[1)] Source: Boustead-Hancock 1979, Alber 1983.

I.3 TIME-SERIES AND CROSS-SECTION ANALYSIS OF THE MOST ENERGY-INTENSIVE BRANCHES OF THE MANUFACTURING SECTOR IN EIGHT DEVELOPED COUNTRIES

This section describes an attempt to apply the product-mix approach described in the preceding chapter above to the most energy-intensive branches of eight developed countries (Federal Republic of Germany (FRG), Japan, Austria, Hungary, United Kingdom (UK), USA, Italy, and France). The analysis was carried out for the following branches:

(1)	Iron and steel industries	(ISIC 371)
(2)	Non-ferrous metal industries	(ISIC 372)
(3)	Paper and pulp	(ISIC 341)
(4)	Chemical products	(ISIC 35 without 353,354)
(5)	Non-metallic mineral products	(ISIC 36).

The following data were used:

(1) Final energy consumption by industry branches

For most countries energy data could be obtained from energy balances published by country-specific authorities (Statistical offices (CSO)), ministries, country economists). In the case of the UK energy balances published by ECE were used. For the USA a somehow mixed approach was used: For iron and steel industries ECE balances were used, while for the other branches time series of final energy use were calculated by multiplying base year (1970) ECE data with indices of "energy purchased for heat and power," delivered by the US census of manufactures. As energy use data originate from various sources, reclassification of sectors and recalculations to a common terajoule basis were necessary. In general these figures agree with IEA data.

(2) Total production (gross output) in constant (1970) US$ by industry branches

For some countries outputs in constant prices were made available by CSO's. For other countries base year outputs were multiplied with the most adequate production indices.* Outputs expressed in constant values of different currencies

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* Here and later output figures in constant prices calculated on the basis of production indices which are compiled by UN, refer to indices of value added, and not shipments. It

were recalculated into millions of 1970 US$ by applying 1970 exchange rates.

(3) Total output of certain energy-intensive products in tons

In order to discover structural changes not only between industries, but also within industries, fifteen energy-intensive commodities (Table 6) of each industrial sector were selected. Commodity output in tons was supplied by UNIDO (based on the UN Yearbook of Industrial Statistics, Vol. II).

(4) Prices and energy intensities of commodities

In order to combine total outputs of industries with total outputs of commodities the commodity data in tons were valuated by adequate prices of the base year (1970) (Table 6). For most countries world market prices were calculated by using average unit values from (1970) foreign trade statistics supplied by UN. For Hungary, where world market prices are not appropriate, actual Hungarian producer prices were applied.

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makes these estimates biased if the share of intermediate costs is changing over time. We found for some countries (FRG, Austria, USA and USSR) that the difference in 10 years cannot exceed a few percentage points.

The indices reported by C. Doblin (1984) show that the growth trends for gross production (gross value added) have been quite similar in the FRG in the past decade. This means that the share of intermediate input has remained stable for most of the period, except for some significant changes during the years of recession; these latter changes may have been due to inventory accounting or imports.

Comparison of production indexes in the FRG, 1970–31 (index numbers, 1970=100) are as follows:

[a] Gross production denotes turnover excluding sales, for movement of stocks.

[b] Net production denotes gross production excluding the value of materials used; this is similar to the German gross value added.

Table 6. Prices and energy intensities of selected energy-intensive products.

Industry	ISIC 6-digit	Commodities	Energy intensities GJ/ton	Prices in 1970 US$/ton
Steel	371016	steel for castings	19	120.—
	371019	steel ingots	19	120.—
Non-ferrous metals	3720041	primary copper	17	1430.—
	3720221	primary aluminum	80	600.—
	3720431	primary zinc	40	310.—
Non-metallic mineral products	369201	quicklime	5	16.—
	369204	cement	5	18.—
Pulp and paper products	341110	pulp sulphite	20	170.—
	341113	pulp sulphate	20	130.—
Chemicals	351158	ammonia	41	50.—
	351159	caustic soda	12	40.—
	351173	calcium carbide	16	90.—
	351121	methanol	38	70.—
	351105	acetylene	66	80.—
	351201	nitrogenous fertilizers	10	50.—

The energy intensities (TJ/1000 tons) used are based on various sources* and related values shown in Table 6 give the first overview of the importance of a clear identification of various commodities to analyze energy demand by these industries.

Table 7 presents the energy output ratios for eight countries and five industries. Due to data constraints for Japan and Hungary a breakdown of basic metal industries into steel industries and non-ferrous metal industries was not possible; a sixth industry showing total basic metal industries' energy coefficients was therefore compiled. From these data shown only for benchmark years 1970, 1975, and 1980 one finds big differences between countries in energy input within each industry: the energy coefficient for the aggregated "basic metals" industry varies from about 50 TJ/mill. US$ to 120, i.e., a 2.5 coefficient and for a more homogeneous industry "pulp and paper," a coefficient of 2 times applies to the USA compared to

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* Boustead-Hancock (1979), Eurostat (1982).

Table 7. Energy coefficients 1970, 1975, 1980, TJ/mill. US$.

		Basic metals	of which		Chem.	Pulp and paper	Non-metallic mineral products
			Steel	Non-ferr.			
FRG	70	52.1	96.2	22.2	28.4	59.3	58.0
	75	44.1	78.3	21.8	21.8	57.7	47.0
	80	40.7	74.0	24.0	18.9	49.7	40.3
Austria	70	122.8	192.0	26.6	.	44.6	90.4
	75	120.0	196.3	24.6	.	42.5	82.1
	80	101.1	184.0	19.4	.	45.2	73.1
Japan	70	51.2	.	.	80.1	30.7	59.2
	75	53.3	.	.	65.7	30.0	58.8
	80	39.7	.	.	52.1	24.8	59.7
Hungary	70	91.8	.	.	55.4	.	123.4
	75	86.3	.	.	55.2	.	107.0
	80	80.7	.	.	42.0	.	87.4
UK	70	78.1	105.3	20.9	.	41.5	94.8
	75	71.7	97.6	28.0	.	41.7	64.1
	80	51.5	75.3	21.6	.	30.5	61.2
France	70	107.3	107.3	107.2	55.1	45.1	109.8
	75	110.3	110.4	110.0	52.3	41.1	96.0
	80	95.6	94.8	98.4	45.4	36.1	90.1
USA	71	69.1	87.3	40.1	59.4	53.1	70.9
	75	62.2	77.4	36.1	51.3	45.8	60.5
	80	58.2	77.5	32.7	40.3	40.6	54.4
Italy	70	60.5	63.1	44.1	57.8	31.5	260.9
	75	60.8	61.1	58.6	43.8	27.3	245.5
	80	50.5	52.8	35.6	27.1	19.6	203.7

Japan. At the aggregated level one observes significant declining trends in energy coefficients for some countries in all industries (USA) while for other countries like France or the FRG these trends either do not exist or are rather modest. All these different patterns of energy demands by industries have been analyzed on the basis of econometric models described above. Of course, structural shifts at the commodity level may play a significant role when energy requirements of commodities within an industry like nonferrous metals or chemicals differ by 4-6 times. It is also important to note that for industries with rather similar structures (across countries) the energy coefficient varies less than for more heterogeneous structures (compare nonferrous metals and paper and pulp energy coefficients).

To get a general overview of the possible impact of structural effects on energy requirements Table 8 shows the percentage share of the value of 1970 US$ of identified most energy-intensive products in total constant price gross output of each industrial branch, by country.

Table 8. Percentage of identified energy-intensive output in total output.

		Steel	Non-ferr.	Basic metals	Non-metallic mineral products	Chem.	Pulp and paper
FRG	70	56.9	14.8	29.5	16.5	1.9	5.7
	75	47.3	18.6	26.7	13.8	1.4	6.6
	80	50.4	16.1	26.3	11.8	1.1	5.4
Austria	70	92.9	16.8	61.0	31.1	.	18.6
	75	93.8	15.6	59.0	29.7	.	15.5
	80	94.5	13.8	53.9	26.9	.	16.8
Japan	70	.	.	32.4	14.0	1.8	10.6
	75	.	.	30.6	16.4	1.2	11.1
	80	.	.	27.3	18.3	0.7	10.9
Hungary	70	.	.	33.7	23.7	8.4	.
	75	.	.	32.0	25.5	6.4	.
	80	.	.	31.1	23.3	4.6	
UK	70	47.0	4.0	33.1	9.6	.	0.7
	75	44.9	9.7	31.8	8.7	.	0.6
	80	35.1	11.3	24.6	8.6	.	0.3
France	70	49.8	25.3	45.2	21.1	2.6	7.0
	75	49.0	24.9	44.0	18.5	2.4	7.1
	80	47.2	24.4	42.2	17.0	1.5	5.0
USA	71	38.6	30.0	33.3	7.7	2.4	16.6
	75	28.2	25.0	31.6	6.7	2.3	14.8
	80	26.5	19.3	30.4	7.1	2.2	16.2
Italy	70	43.8	19.9	42.2	66.1	3.3	0.8
	75	48.7	22.4	45.5	68.4	2.3	0.6
	80	45.7	23.2	44.4	68.9	1.6	0.2

This table shows clearly that the share of selected energy-intensive goods in total industries' output varies from industry to industry. The best sampling is for the iron and steel industry, while for chemicals – due to the big share of petrochemicals – it is rather low. Of course the big share of intra-industry transactions plays an important role in the underestimation of the share of selected commodities in output. In case of the pulp and paper industry the share of pulp is very low in the UK where imports take about 80% of pulp use.

At this stage of the analysis we note that in almost all countries and industries the share of energy-intensive products goes down. Consequently, and also because of the increasing use of energy saving technologies, the energy/output ratios also decrease. The main differences of industries' energy coefficients between countries can also be partly attributed to varying production structures. The large energy output ratio of basic metal industries in Austria corresponds to a high percentage of energy-intensive products. The same is true for the non-metallic minerals industries in Italy. The relatively small energy coefficients in the basic metal sector in the FRG and in Japan is not only caused by the use of highly efficient technologies, but it is also due to a relatively small share of energy-intensive products.

To quantify the impact of changing production structures and to separate this from "other effects" (technical progress, interfuel substitution effects, unidentified product-mix effects) a version of model 1 was used.

The modification of the model is due to the fact that we have used energy requirements as expressed per ton of each commodity (Table 6). With the notations previously used we may write down a regression model:

$$E_{jk}(t) = \beta_{jk} \exp(\lambda_{jk} \cdot t) \cdot \sum_{i} \tilde{e}_{ijk} \cdot Q_{ijk}(t) + \varepsilon_{ik}(t) \qquad (7)$$

where

i	index of commodities
j	index of industry
k	index of country

and parameters to be estimated

β_{jk}	a scaling parameter to be estimated and which may differ from country to country
λ_{jk}	rate of energy-saving technological progress.

Of course, if equation (7) takes into account all commodities produced by an industry, the only weaknesses of assumptions are that the energy-saving technical progress is on average equal over the commodities (λ_{jk} is the same for all commodities). A scaling parameter estimate may reflect some inter-country differences in the energy use by an industry, which are due to fuel-mix, differences in capital stock age, etc.

We were aware of the fact that within each industry there are other commodities which are not considered in the model explicitly, i.e., a part of output and energy inputs is not covered by the sample of commodities. To identify these terms we estimated the rest of an industry output and the corresponding energy input by deducting from the total output the value of commodities covered under the fixed prices (see table 6). Therefore, there appears in the model a "commodity" in value terms and its base year energy/output ratio.

Table 9, which shows the data and calculations for the nonferrous metal industries in the FRG may serve as an illustration of the method applied to all other industries and countries: the first two columns (energy consumption and output) were available at the industry level. Column 3 shows the energy output ratio which gives a first impression of the development of the energy requirement per unit of nonferrous industries' gross output in the FRG. As emphasized above, the energy output ratios of an industrial branch does not only serve as an indicator of technical progress, but reflects also the changing percentages of energy-intensive products in total output. Total output of nonferrous metals is subdivided into three explicitly identified commodities, namely zinc, aluminum, and copper, and into a fourth category, "other output," which is calculated as a residual. While "other output" and copper are relatively less energy-intensive, zinc and especially aluminum are highly energy-intensive products. The value share of energy-intensive aluminum in total output decreases between 1965 and 1970 from 8.5% to 6.5%. Consequently, and of course also due to efficiency improvements, the energy/output ratio of the whole branch drops from 31 TJ/mill. of US$ to 22 TJ. In the early 1970s, i.e., from 1970 to 1974, the energy-intensive products grew faster than other commodities. The share of zinc and aluminum grew from 6.5% in 1970 to 12% in 1974. Consequently the energy output ratio grew from 22 to almost 26 TJ per million dollars of output. As a result of the first oil shock the value share of energy-intensive zinc and aluminum dropped from 1974 to 1975 from 12% to 10%. Again the energy output ratio went down from 26 to 22 TJ. In the late 1980s a growing output share of the most energy-intensive aluminum made the energy output ratio grow from 22 to 24 TJ. This example of the close relationships between energy intensity of production (share of energy-intensive products) and energy output ratio illustrates the importance of structural change.

To separate the product-mix effects from energy savings we calculate a time series of energy requirements without energy saving technical progress by

Table 9. Calculation of energy/output ratios at constant (micro)energy intensities for the nonferrous metal industries in the FRG

	(1) Energy in TJ	(2) Output in mio 1970 US$	(3)= (1)/(2) Energy output ratio	(4) Outputs zinc 1000 t	(5) Outputs alum. 1000 t	(6) Outputs copper 1000 t	(7) Value of zinc, alum., copper in mio 1970 US$	(8)= (2)-(7) Other output	(9) Energy require- ment at const. energy intens.	(10)= (9)/(2) Energy output ratio at constant energy intensities	
1965	63 764	2970	30.8	107	234	227	498	1572	49 940	24.1	6.7
1966	64 555	2083	31.0	123	244	211	486	1596	51 467	24.7	6.3
1967	61 743	2224	27.8	103	253	171	428	1795	53 631	24.1	3.7
1968	65 463	2585	25.3	101	257	228	512	2073	58 917	22.8	2.5
1969	70 062	2895	24.2	109	263	200	478	2418	64 299	22.2	2.0
1970	75 715	3415	22.2	123	309	196	504	2911	75 715	22.2	0
1971	80 782	3670	22.0	111	428	202	580	3090	87 480	23.8	-1.8
1972	84 297	3984	21.2	213	445	199	618	3317	96 936	24.3	-3.1
1973	95 925	3767	25.5	241	533	200	681	3086	100 995	26.8	-1.3
1974	104 214	4093	25.5	250	689	220	806	3288	117 137	28.6	-3.1
1975	98 766	4530	21.8	174	678	268	844	3186	119 874	26.5	-4.7
1976	104 272	4705	22.2	202	697	289	894	3811	124 706	26.5	-4.3
1977	110 921	4742	23.4	210	742	283	915	3827	128 770	27.2	-3.8
1978	110 980	5075	21.9	214	740	228	836	4239	133 879	26.3	-4.4
1979	115 198	4680	24.6	211	742	187	778	3902	128 272	27.4	-2.6
1980	115 461	4820	24.0	225	731	186	774	4045	130 032	27.0	-3.0
Price 1970 (US$/ton)				310	600	1430		-			
Energy intensity for base year (1970) per products:											
GJ/ton				40	80	17		-			
GJ/1000 US $				129	133	12		15			

multiplying outputs of different commodities with constant energy efficiencies. Column 9 (Table 9) shows an energy consumption which would occur if there was no attempt to save energy. Column 10 presents a series of energy/output ratios at constant energy intensities but varying product-mix shares. The difference between column 10 and the actual energy/output ratio (column 3) can be attributed to energy savings, use of more efficient fuels and unknown product-mix effects. These "other effects" would make the energy/output ratio decline at an average rate of 2.7% per year. As the energy-intensive products tend to grow faster than other output, the energy/output ratio declines only with 1.5% per year.

The results of the regression analysis of energy requirements by means of equation (7) seems to be promising for identifying the role of product-mix and "other effects."

In Tables 10–12 the results of the analysis for 8 countries and 4 industries are presented. Table 10 shows the annual growth rate of the energy coefficients, while Tables 11 and 12 present a breakdown of these growth rates into growth rates of product-mix effects and growth rates due to "other effects," respectively.

With a few exceptions product-mix effects in all countries and industries have a significant explanatory influence on changes in the energy output ratio.

Steel Industry

At least 25% of the decline of the energy output ratio is found to be attributed to changing production structures. Each country moves its production structure from energy-intensive crude steel production to less energy-intensive products (e.g., special steel, finished rolled products). Nevertheless there is a significant movement towards less energy-intensive processes.

As shown in Table 13, remarkable changes in the production of steel produced by different processes were noted during the 1970s. In almost all countries a significant shift from the inefficient open hearth to more efficient processes (oxygen, electric arc) contributed significantly to the decline of energy requirements per unit of output. Especially France and the UK, which used in 1970 a high percentage of less efficient technologies, could improve their process structures. While France shifted permanently from the open hearth to oxygen furnaces, the UK increased its oxygen as well as its electric arc capacity. Also the FRG, the USA, and Italy were able to restructure their process mix and consequently improve their energy efficiencies. As Japan used already in 1970 a small percentage of less efficient open hearth technologies, the structural improvements of total steel

Table 10. Average annual percentage rate of change of energy coefficients (*t*-value in parentheses).

		Basic	*of which*		Build.	Chemicals.	Pulp and
	Period	Metals	Steel	Non-ferr.	materials		paper
FRG	(1965–80)	−2.6	−2.5	−1.5	−4.3	−5.6	−1.0
		(9.3)	(7.8)	(2.8)	(24.3)	(17.2)	(3.8)
Austria	(1965–80)	−2.0	−0.7	−3.8	−2.9	.	−0.8
		(9.4)	(4.8)	(9.3)	(16.2)		(1.7)
Japan	(1970–80)	−2.8	.	.	+0.9	−4.0	−2.5
		(4.6)			(2.5)	(10.1)	(5.1)
Hungary	(1970–80)	−1.3	.	.	−4.0	−0.7	.
		(14)			(9)	(0.7)	
UK	(1970–81)	−3.4	−3.0	−0.3	−3.2	.	−3.9
		(6.6)	(7.4)	(0.2)	(4.6)	.	(5.7)
France	(1970–81)	−1.2	−1.3	−0.8	−1.9	−1.5	−1.4
		(4.9)	(4.8)	(3.2)	(8.3)	(5.4)	(6.1)
USA	(1971–80)	−2.1	−1.7	−2.1	−2.7	−3.6	−3.1
		(3.8)	(2.6)	(3.1)	(14.6)	(5.6)	(9.4)
Italy	(1970–81)	−1.5	−1.5	−2.2	−2.6	8.2	−4.2
		(3.9)	(4.3)	(1.3)	(5.0)	(12.2)	(8.4)

production were comparatively smaller than in the other countries. Japan merely shifted from oxygen to electric arc steel production. On the other hand, electric arc steel requires more energy at the stage of crude steel production (~7 GJ/t) than basic oxygen furnaces (~1 GJ/t). On the other hand, electric arc furnaces use scraps as input, while oxygen furnaces rely on a high share of energy-intensive pig iron (22 GJ/t). Therefore, though Japan's energy consumption in steel production per ton of steel grew from 1.75 GJ in 1970 to 2.12 GJ in 1980, its total energy requirement per unit of output of iron and steel industries declined in that period.

However, the average annual rates of increase of energy efficiencies in pig iron production and steel production, respectively presented in Table 13, indicate that there was a global improvement of energy efficiencies in the iron and steel industries between one and two percent per year. The results coincide with the econometric estimates presented in Table 12.

Table 11. Contribution of (identified) product-mix effects: average annual percentage rate of change of energy-intensive production (*t*-value in parentheses).

	Period	Basic Metals	*of which*		Build. materials	Chemicals.	Pulp and paper
			Steel	Non-ferr.			
FRG	(1965–80)	−1.3	−1.3	+1.2	−2.6	−1.8	−0.1
		(4)	(3.7)	(4.0)	(25.9)	(16)	(1.3)
Austria	(1965–80)	−1.3	−0.0	−4.1	−1.0	.	−0.6
		(8.9)	(0.9)	(10.0)	(9.5)		(4.1)
Japan	(1970–80)	−1.9	.	.	+1.9	−0.4	0.0
		(6.3)			(7.7)	(10.7)	(0)
Hungary	(1970–80)	−1.9	.	.	0.0	−0.9	.
		(2.4)			(0.5)	(2.9)	
UK	(1970–81)	−0.8	−0.5	+2.4	−0.2	.	−0.1
		(2.4)	(2.3)	(9.3)	(3.5)	.	(5.5)
France	(1970–81)	−0.3	−0.3	−0.2	−0.6	−0.7	−0.2
		(10.3)	(10.2)	(4.5)	(7.6)	(4.7)	(4.3)
USA	(1971–80)	−0.3	−0.1	+0.3	−0.1	−0.3	−0.1
		(2.7)	(0.4)	(1.9)	(1.3)	(1.3)	(0.5)
Italy	(1970–81)	0	−0.1	+1.0	+0.1	−1.4	−0.1
		(0.1)	((0.5)	(5.4)	(1.3)	(20.4)	(5.1)

Non-Ferrous Metals

While in most other industrial branches a significant trends towards less energy-intensive products was observed, in the non-ferrous metals industries of at least four (FRG, UK, USA, and Italy) out of six countries a movement towards more energy-intensive commodities is seen in Table 11. Hence, because the overall energy coefficient decreases in these countries (see Table 10), the average rate of the energy saving technical progress is found in Table 12 to be larger in these countries than the growth rate of the energy coefficients itself. Austria, Japan, France, and the USA shift from energy-intensive primary aluminum production to secondary aluminum production (recovery of scrap). The FRG, Italy, and especially the UK increased their primary aluminum capacity.

Table 12. Contribution of energy saving technical progress and other effects (interfuel substitution, hidden product-mix effects); average annual percentage (*t*-value in parentheses).

	Period	Basic Metals	*of which* Steel	*of which* Non-ferr.	Build. materials	Chemicals.	Pulp and paper
FRG	(1965–80)	–1.3	–1.2	–2.7	–1.8	–3.8	–0.9
		(17)	(11)	(6.9)	(12.8)	(14)	(3.8)
Austria	(1965–80)	–0.7	–0.1	+0.3	–1.9	.	–0.2
		(5.4)	(4.9)	(3.3)	(9.4)		(0.5)
Japan	(1970–80)	–0.9	.	.	–1.0	–3.6	–2.5
		(1.8)			(4.8)	(9.1)	(6.2)
Hungary	(1970–80)	–1.1	.	.	–3.9	+0.2	
		(13)			(10)	(0.2)	
UK	(1970–81)	–2.6	–2.5	–2.7	–3.0	.	–3.8
		(8.4)	(8.7)	(2.5)	(4.6)		(5.7)
France	(1970–81)	–0.9	–1.0	–0.6	–1.3	–0.8	–1.3
		(3.7)	(3.8)	(2.4)	(6.4)	(3.6)	(5.7)
USA	(1971–80)	–1.8	–1.6	–2.4	–2.6	–3.3	–3.0
		(3.3)	(2.7)	(4.5)	(17.6)	(6.4)	(13.8)
Italy	(1970–81)	–1.5	–1.4	–3.1	–2.7	–6.8	–4.1
		(3.9)	(3.6)	(1.7)	(5.3)	(9.5)	(8.2)

Building Materials

While in all other countries the energy output ratios decreased, increased Japan on account of a considerable growth of cement production. Therefore significant trend towards energy savings was found in all countries, including Japan after eliminating the product-mix effects (see Table 12). The overall annual percentage change of "other effects" (energy savings, etc.) is around 2%.

Chemicals

The chemical industry is one of the most heterogeneous industries. Unfortunately no detailed data on energy inputs were found and therefore a breakdown into different branches was not possible. In order to capture at least some of the considerable shifts in production structures of the chemical industries, some energy-intensive products were identified. Therefore, especially in the chemical

Table 13. Pig iron and steel production by process and country

		Energy intensities of				Crude steel production by type of furnace (percentage of total crude steel production)		
		Blast furnaces		Steel works				
		GJ/ton pig iron	annual percentage change	GJ/ton steel	annual percentage change	Oxygen	Electric arc	Open hearth
USA	1970	not available				48.2	15.3	36.5
	1981					60.5	27.9	11.6
USSR	1970	22.18	-0.3	3.82	-1.8	18.99	4.77	76.24
	1980	21.63		3.19		31.25	5.86	62.89
JAPAN	1970	19.13	-1.2	1.75	+1.9	79.2	16.7	4.1
	1980	17.00		2.12		75.7	24.4	-
FRG	1970	24.94	-2.7	2.48	-2.1	55.8	9.9	34.3
	1980	19.06		2.02		78.4	14.6	6.7
FRANCE	1970	28.19	-1.4	2.47	-1.9	29.4	9.9	60.7
	1980	24.56		2.04		83.1	14.6	2.3
UK	1970	24.75	-0.3	5.11	-4.2	32.1	19.5	48.3
	1979	24.05		3.49		60.1	34.4	5.5
ITALY	1970	18.41	-0.7	4.11	-0.3	30.8	39.7	29.5
	1980	17.23		4.00		45.3	53.0	1.7

Source: ECE, Strategy for Energy Use in the Iron and Steel Industries;
American Iron and Steel Institute, Annual Statistical Report 1983.

industry, a considerable part of energy-relevant shifts of the production structure could not be identified and is left to the "other effects." Yet, even in a limited commodity sample, significant structural changes towards less energy-intensive products were found.

Paper and Pulp

Compared to other industries just a weak shift from energy-intensive pulp to relatively less energy-intensive paper and paper products was found.

Conclusions

Looking at the structural changes in Table 9 for steel processes and Table 11 for product-mix, two alternative interpretations suggest themselves, for policy purpose: The shift in output-mix towards less energy-intensive commodities can be thought to be permanent, i.e., related to a long-term move, or temporary, i.e., due to a cyclical slow-down of the economy. The importance of this issue cannot be underestimated, since a permanent shift of industrialized economies towards less-intensive commodities would strongly affect the international division of labor. Unfortunately no general answer can be given at this stage in an analysis restricted to the 1970s (the picture will be much clearer when the recession is over), but the report already offers a few interesting conclusions. In some cases, e.g., for non-ferrous metals in the Federal Republic of Germany, some qualitative evidence of temporary changes is found. The case of Iron and Steel, which is quantified in the study for seven countries, is yet of a different type. A permanent shift towards less-intensive processes, which can be assimilated to a long-term technical progress suggests that little ground, if any, is prepared in the seven developed countries for a new international division of labor in steel.

I.4 STRUCTURAL SHIFTS IN BASIC MATERIALS INDUSTRIES OVER REGIONS

The UNIDO data base provides an opportunity to build a consistent set of time series of gross output by industries in constant 1970 prices (with some deficiencies mentioned above) and main energy-intensive commodities for which reliable estimates of energy requirements have been compiled for various countries (a list of industries and commodities as well as energy intensities by products are given above in Chapter I.3, Table 6. The coverage of regions by country data is given in Appendix I.1).

Here, we faced the problem of missing data: data for the years 1970–1980 were some times missing or there were only data in current prices or only indices of rates of growth, but without values for any year. Some regions are covered much better in this respect than others. In the first set of regions, i.e., where almost all data are available, there are Regions 1 (North America), 2 (Western Europe), 4 (Japan), and 8 (Indian Sub-Continent). Some simple adjustments were performed to cover socialist European countries (Region 3) as for some of them (Hungary, Czechoslovakia, Poland) all data were available and for others rates of growth were reported (USSR, GDR, Romania, Bulgaria); the industrial gross output values for 1970 were taken from the input–output data available at IIASA, except for Romania. According to the number of countries put into our sample, Region 6 (Latin America) was better covered than Region 7 (Sub-Saharan Africa). The disaggregation of values reported by UNIDO data base (if there are known aggregates) was done on the basis of any information available for other years (value added, employment) or applying average shares of sub-industries derived from other countries' data. If no quantitative information was available, we assumed equal weights for sub-industries for each aggregated one. This procedure was applied only to few countries, mainly some Asian and African countries.

To test the usefulness of this procedure our aggregates were compared with data from other sources, such as UN, FAO, ECE publications, US Bureau of Mines, Metals Statistics, etc. Commodity production volumes are well covered for every region for iron and steel, aluminum, copper, pulp, fertilizers, etc., while for some chemical products the situation is not satisfactory.

After this general information on the procedure, it is worthwhile considering the impact of sampling on the world production as a whole (Table 14).* One can see

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* It is relevant to note that the sample does not differ from commodity to commodity, i.e., the same set of countries is used for *every* commodity.

from this table that the bulk of production of energy-intensive products listed is covered within the framework of the study. Only for three commodities (acetylene, quicklime, and crude steel for casting) our sample covers less than 90% of the world production.

Table 14. Effect of sampling on the representation of the total world production by commodities for the year 1975.

Commodity ('000 tons) Titles	ISIC codes	1978 production, million tons Our sample (I)	 World total* (II)	Share (I/II)
Woodpulp, sulphite & soda	341110	55454	55649	99.7
Woodpulp, sulphate	341113	11926	11844	100.6
Acetyline	351105	773	895	86.4
Methanol	351121	6557	6627	98.9
Ammonia	351158	36971	36612	101.0
Caustic soda	351159	25578	26007	98.3
Caustic carbide	351173	6354	4605**	138**
Nitrogenous fertilizers	351201	40003	41141	97.2
Quicklime	369201	98671	111640	88.4
Cement	369204	685058	696075	98.4
Crude steel for castings	371016	15246	16958	89.0
Crude steel, ingots	371019	622103	637738	97.5
Copper, refined, unwrought	3720041	7643	7610	100.3
Aluminum, unwrought	3720221	11794	12016	98.2
Zinc, unwrought	3720431	4584	4888	93.8

* Data source: UN Yearbook on Industrial Statistics, Vol. 2, Commodity Production Data, N.Y., UN, 1981.

** For ISIC 351173 the difference is explained by the fact that for 1975 the data were not repored for the USSR in the UN Yearbook, while they are reported for 1970 and 1976.

To give an overview of the shares of different regions in the world production of the selected energy-intensive goods the data (in percentage) are shown in Appendix I.2. From these data and the growth of goods produced in developed countries (Table 15) it follows that despite the fast growth of the manufacturing sector in many developing countries the shares of selected energy-intensive commodities were still low in the 1970s. For example the West Asia–North Africa, Indian Sub-Continent, and East and South-East Asia all together do not exceed 1% of the wood pulp (sulphite and soda) production, Sub-Saharan Africa's production of cement is less than 1% of the world volume of production. Steel figures in that regions are less than 0.1% of world output and in the West Asia–North Africa 0.2%.

Structural changes in the regional location of energy-intensive products differ among commodities, but in general it follows from the data (Appendix I.2) that most of the developing countries increased their shares in the production of energy-intensive goods. For example, in wood pulp production (ISIC 341110) Region 6 (Latin America) constitutes now 5.5%, while in 1970 it was less than 2%. Acetylene production (ISIC 351105) in this region increased from 1.2% to almost 7%, for methanol (ISIC 351127) from 0.3% to 2%. For basic chemical products changes are also clear – Japan's share decreased for ammonia (ISIC 351158) from 3.4% to 0.2%, while Latin America's share doubled from 2.4% to 5%, for caustic soda (ISIC 351159) East and South-East Asia and Latin America increased their shares almost two times, for caustic carbide (ISIC 351173) CPE, Asia's share increased more than three times and Latin America's share two times. One of the traditional products – cement (ISIC 369204) shows a similar pattern – all developed regions (1–5) have decreased their share, while the share of developing regions, such as CPE, Asia, Latin America, East and South-East Asia, and the West Asia–North Africa almost doubled. Now the share of cement production is 9% in North America, 10% in Japan, 8.4% in Latin America, 10% in CPE, Asia, and more than 4% in East and South-East Asia and West Asia–North Africa (each).

Less significant changes happened in steel production (ISIC 371019) where only East and South-East Asia showed a jump from 0.1% to almost 1%, while other developing regions increased their shares at a modest rate (Latin America from 2.25% to 3.2%, CPE, Asia from 1% to 5.4%). Regional specialization in non-ferrous metal production (within the framework of this study) shows that only CPE, Asia increased significantly (by two times) its share in copper and aluminum, while the shift in aluminum production toward Latin America (Brazil) and the "Other developed" regions (Australia, New Zealand and South Africa) is a new

Table 15. Production Figures for the Energy-Intensive Commodities by Developed Regions

	1970	1973	1978	1980	1981	1982
351158 Ammonia						
North America	11.3	12.3	15.2	17.3	16.8	
Western Europe	8.83	10.96	13.3	10.6	7.8	
Japan	.90	.54	.13	.12	.10	
351159 Caustic Soda						
North America	10.1	10.7	10.8	12.6	11.2	
Western Europe	5.43	7.18	7.0	7.03	6.54	
Japan	2.61	3.14	2.70	3.06	2.79	
351173 Caustic Carbide						
North America	.718	.263	.236	.235	.234	
Western Europe	2.26	1.34	.908	.881	.680	
Japan	1.25	.58	.56	.55	.50	
351201 Nitrog. Fertilizers						
North America	8.22	9.34	11.08	12.9	13.5	
Western Europe	6.47	7.09	8.48	10.2	10.0	
Japan	1.82	2.13	1.61	1.62	1.43	
369204 Cement						
North America	74.9	87.6	88.6	79.9	76.3	
Western Europe	181	208	216	217	220	
Japan	57.2	78.1	84.9	88.0	84.8	
371019 Steel						
North America	130.3	150.0	139.0	117.1	124.3	
Western Europe	153.2	169.8	153.7	148.3	145.3	
Japan	91.9	117.8	101.1	110.2	100.5	
3720041 Copper						
North America	2.06	2.17	1.86	1.89	1.99	
Western Europe	.92	1.06	1.20	1.21	1.11	
Japan	.61	.87	.91	.96	.98	
3720221 Aluminum						
North America	4.57	5.03	5.40	5.72	5.60	
Western Europe	1.92	2.77	3.41	3.73	3.68	
Japan	.75	1.10	1.06	1.10	.78	
3720431 Zinc						
North America	1.21	1.06	0.90	0.93	.96	
Western Europe	1.24	1.43	1.57	1.67	1.69	
Japan	.66	.83	.74	.70	.63	

phenomenon,* which must be taken into account in forecasting. The data presented in Table 15 also show the stagnation in the production of energy-intensive commodities in developed regions. Recent observations in metal production gives us further strong signals to assume a stagnation of the production of metals in developed countries.

The year 1983 was the fourth successive year for the aluminum production in the Western World to go down. Capacities in the North continue to shut down, while an increase of production is observed in Sub-Saharan Africa and the "Other developed" region and in Latin America. This might extend to the future allocation of primary aluminum production.

Production of refined copper stays almost at a constant level in recent years and shares of different regions are also stable.

With zinc there is a further decline in production, in addition to the decrease in North America, Western Europe, and Japan, while a continuous growth is observed for Latin America and Sub-Saharan Africa.

A general overview of the situation in the Western World metal consumption is given in Appendix I.3, which shows a significant slowdown in metal demand in the last decades.

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* There are estimates that in the late 1980s Japan will produce only 30 thousand tons compared with 1.1 millions tons in the 1970s and 350 thousand tons in 1982.

I.5 COMPILATION OF ENERGY/OUTPUT RATIOS BY INDUSTRIES AND REGIONS

In Chapter I.3 changes in the energy/output ratios were analyzed for eight developed countries and subdivided into product-mix effects within industries and into other effects (energy savings, hidden shifts in the production structures, etc.). In this chapter an attempt is made to apply to world regions the methods which were tested previously.

The analysis of energy/output relationships of certain industries on a global level is limited by data restrictions. For most developing and centrally planned countries energy use by industrial branches is not available. Therefore we had to choose a somewhat different approach in the global analysis.

The method is based on two hypotheses:

- The energy intensity of a specific commodity or a homogeneous group of commodities does not differ very much between countries (best practice prevails);
- Energy saving technological progress grows with a constant exponential growth rate, which differs from industry to industry, but is equal among countries.

This means that differences in energy intensities between countries at an aggregated level are caused by different production structures. It also implies that changes in the product-mix over the years will yield different countries' patterns of energy coefficients over time.

It is clear that both hypotheses do not hold in confrontation with reality: the energy output ratio in steel industries in Poland or Bulgaria is much higher than it is for Japan or Italy. Technical progress embodied in new installations is much higher in countries with growing capacities than in countries with old plants. Therefore the results of the analysis using artificial data is in fact meant to detecting relevant differences in production structures among world regions.

On the other hand, if we compare developed regions with developing regions, the differences as well as the different changes of production structures are an important and considerable factor in energy analysis

The data requirement of this analysis is as follows:

- Commodity production in tons. Time series on the production of selected (see Table 6) commodities by country were supplied by the UNIDO data base on tape which covers more countries than the UN Yearbook of Industrial Statistics, Vol. II.
- Time series of production indices as well as base year (1970) values for gross output were also supplied by the same source, which covers many countries as well, when compared with the UN Yearbook of Industrial Statistics, Vol., I.
- Exchange rates of 1970 were used to obtain total production in US$. The industries used for this analysis are the same as reported in the production of basic intermediate goods (Table 6).

The approach used for the global analysis is in some sense similar to the method used before. But instead of estimating technical progress from actual energy data, energy coefficients without technical progress were compiled first and the average energy saving ratios at the level of subindustries were applied. At first the production indices for each country were multiplied with the base year (1970) values for gross output to obtain time series in constant price outputs. With the deficiencies of this method discussed above these time-series are treated as output values, later aggregated into 11 regions.

Energy requirements of selected products were compiled by multiplying series of commodity production in tons with commodity-specific intensities (see Table 6). The production value of the selected commodities was found in a similar way, multiplying production in tons by commodity prices in 1970 dollars.

The estimation of both the output value of the rest of commodities and its energy requirements is similar to that described in Chapter I.4. The not-identified residual output by industries was calculated by subtracting identified commodity output from total outputs. Adding up energy consumption of commodities produced in the respective industry and residual outputs multiplied by average energy output ratios for residual outputs, calculated by industries and countries in the previous section, gives total energy requirements at constant micro-energy intensities. Applying average annual growth rates estimated in the previous section yields artificial energy consumption.

The flowchart (Figure 7) gives a graphical display of the types described above and may illustrate the calculation procedure.

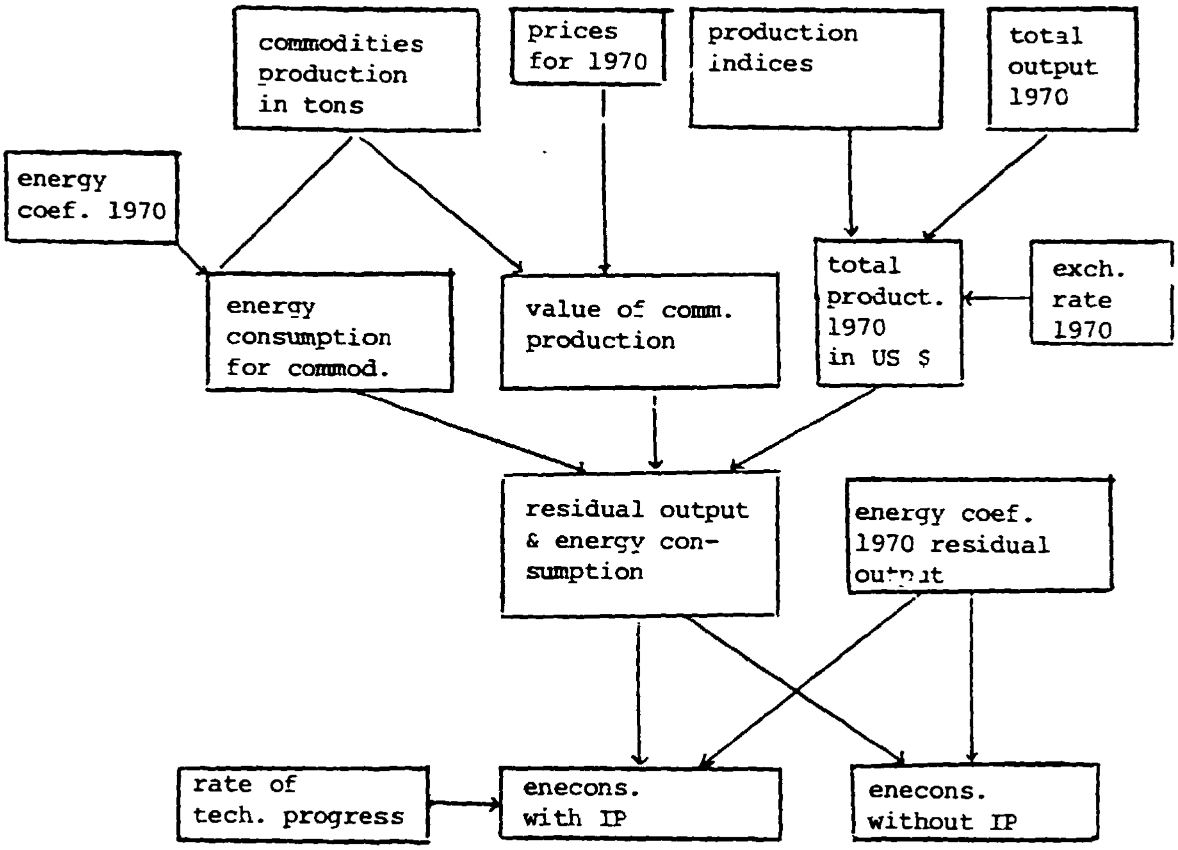


Figure 7. Procedures applied to construct a data set of energy intensity analysis.

After aggregating the energy requirements of the basic products sector as a whole we made a short-cut test of the reliability of both energy balances data for selected developing countries and the procedure applied (when average energy intensities are taken equal to any country). This was done country by country for those which provide time-series data on energy consumption in the industrial sector (see Appendix I.4). In general the growth of energy used by the industrial sector does not contradict the data on the growth of the industrial sector and the relative importance of the basic materials sector in an economy. For example, in Indonesia the seemingly strange behavior of energy input between 1970 and 1975 (see Appendix I.4) corresponds to fluctuations in the production of ammonia, nitrogeneous fertilizers, cement. This also proves the usefulness of the approach in studying the relevance of data on energy inputs by simple econometric techniques.

L6 ANALYSIS OF REGIONAL ENERGY INTENSITIES BY SECTORS

Table 16 presents the energy coefficients by industry and region at "constant micro-energy intensities" i.e., when energy intensities are subject to changing production structures in which technical progress is omitted. Pure product-mix effects are analyzed.

Table 16. Energy coefficients at constant micro-energy intensities, (pure product-mix effect) (TJ/million 1970 US$).

Region	Year	Chem.	Non-ferrous metals	Non-met. mineral products	Paper	Steel
North America	1970	68	44	98	54	102
	1981	63	45	91	54	102
Western Europe	1970	64	40	129	48	98
	1981	57	45	130	46	93
Eastern Europe	1970	72	35	208	49	114
	1981	67	34	186	47	118
Japan	1970	56	40	121	47	116
	1981	49	36	123	46	108
Other developed countries	1970	51	41	111	45	112
	1981	47	51	113	45	111
Latin America	1970	76	30	152	44	111
	1981	95	36	142	53	96
Sub-Saharan Africa	1970	47	26	204	–	56
	1981	50	25	200	–	66
West Asia–North Africa	1970	76	32	189	40	67
	1981	120	153	172	39	74
Indian Sub-Continent	1970	57	62	187	37	104
	1981	56	64	175	42	107
East & S-E Asia	1970	103	42	190	37	67
	1981	82	32	190	38	69

Two competing but not contradictory hypotheses will be compared:

- "Resource endowment" hypothesis:

  Regions with relatively high resource endowment (energy in general, gas and oil in particular, ores, wood) tend towards highly energy-intensive basic products (petrochemicals, basic metals, wood pulp, etc.)

- "Industrialization strategy" hypothesis:

  Fastly industrializing regions tend towards energy-intensive basic products, while industrialized regions increase their share of less energy-intensive (high value added) finished and semifinished products.

In general North America (NA), Western Europe (WE), Eastern Europe (EW), Japan (JP), and the "Other developed" region (OD) are considered as already industrialized, while Latin America (LA), Sub-Saharan Africa (TA), West Asia–North Africa (NE), the Indian Sub-Continent (IN), and East and South-East Asia (AS) are considered as developing regions, with LA, IN and AS forcing more or less their industrialization pace.

Indeed, decreasing energy intensities (Table 16) in most industries indicate that in industrialized regions there is a tendency towards less energy-intensive production structures.

The picture for developing countries is not so clear. While LA, TA, NE, and IN have (with the exception of the non-metallic mineral branch) in most cases increasing energy intensities or tendencies towards industrialization, AS shows especially in the chemical and non-ferrous metals branch an industrialized profile. In the following the analysis is carried out by industrial sectors and regions.

The Chemical Industry

As mentioned above, the chemical industry is one of the most heterogenous branches and a considerable part of energy-intensive production might not have been identified with our approach. Therefore the results of the analysis with respect to the chemical industry are limited.

In almost all industrialized regions we obtain a decline of energy coefficients attributable to a decreasing share of identified (Table 6) energy intensive chemicals. Especially NA and JP tend to energy-extensive high value added products. Japan decreased its share of basic industrial chemical production (ISIC 351) in total chemical industries output (ISIC 351, 352) from 65% in 1970 to 50% in 1981. In WE energy-intensive outputs decreased, or they increased less than total chemical industries output. The share of energy-intensive oil or gas based chemicals (ammonia, nitrogenous fertilizers, acethylene) decreased in total output of the chemical industry.

In LA, TA, and NE new capacities of energy-intensive basic chemicals increased the average energy efficiency. Especially NE may serve as an excellent example of the"resource endowment" hypothesis: Because of a large supply of oil and gas, energy-intensive petrochemicals increased rapidly. The production of nitrogenous fertilizers grew from 250,000 tons in 1970 to 1.2 million tons in 1981.

As LA has more crude oil and gas endowed countries (Venezuela, Mexico, Colombia, Brazil, Argentina) than TA (Nigeria), LA moves much faster into energy-intensive chemicals than TA, which again supports the "resource endowment" theory. IN is characterized by a relatively stable energy output ratio. The energy intensities in AS show a serious decrease from 101.5 to 81.8 TJ per million of US$ of chemical industry output. This decrease can be explained by a comparably small growth of energy-intensive products (ammonia, nitrogenous fertilizers, caustic soda) compared to a high growth of total chemical output. But at that point the weakness of the approach applied to the heterogeneous chemical industry is to be mentioned again: just 3% of total chemical industries' output in East- and South-East Asia could be identified. For the residual output 97% a constant energy/output ratio was applied. Therefore structural changes in 97% of output are omitted.

Non-Ferrous Metals

The non-ferrous metals sector is less heterogeneous compared to the chemical industry. Subdivisions between primary, unwrought non-ferrous metals, secondary non-ferrous metals and semifinished products allows for a sufficient explanation. For NA, two mutually exclusive phenomena, a growth of the most energy-intensive aluminum production on the one hand, compared with a decline of zinc and copper production and a shift from primary aluminum to secondary aluminum (recovery of scrap) on the other, causes a constant energy intensity for the whole branch.

In the period 1970 to 1977 the Japanese energy output ratio remained relatively constant. After 1977/78 it started to decline, due to a remarkable increase in the share of aluminum waste recovery in total aluminum production (45% for 1970 to 1977 compared to 75% after 1978). The energy intensities in OD and in LA are characterized by an increase in primary aluminum production in Australia and South Africa as well as in Argentina, Brazil, and Venezuela. Sub-Saharan Africa's aluminum and zinc production is stable while its copper production declines The enormous jump in the energy output ratio in NE is caused by new primary capacities (aluminum in Egypt and zinc in Algeria). The high coefficient is caused by a comparatively large share of primary metals unwrought in total output of nonferrous metals industry. Indian Sub-Continent increased its aluminum capacity in 1974/75. Comparable to JP, AS (Korea, Taiwan) is characterized by a growing share of scrap recovery. While in 1972 the share of secondary aluminum to total aluminum production was 10%, it increased up to 1981 by more than 50%.

Non-Metallic Mineral Products Industry (NMPI)

Compared to all other branches, NMPI shows a complementary picture: Slightly increasing energy intensities in the North (in 2 of 5 regions) compared to decreasing figures in the South. On the other hand, the energy intensities of NMPI are still much larger in developing countries. The main difference between NMPI and the other basic product industries is that the most energy-intensive part of NMPI (building materials) are not as tradeable internationally as other products.

Therefore developing countries developed their energy-intensive building material capacities (cement, lime) earlier than their china, earthenware and glass production, so that in the late 1980s the South forced its less energy-intensive production more than its building materials capacities.

Pulp, Paper and Paper Products (PPP)

The main pulp production regions are NA and WE. While NA contributed (between 1970 and 1981) at a constant share of 57% to total world production, WE decreased its share from 21% to 18%. At the same time LA increased its contribution to world pulp production from 1% to 4%. Consequently the energy intensities of PPP decreased in WE and increased in LA.

Basic Ferrous Metals (BFM)

With two exceptions (EE and LA) the steel industry shows the expected picture: Increasing energy intensities in the South and decreasing coefficients in the North. While in EE crude steel production and total output of the BFM-sector grew simultaneously, in LA the production of finished and semifinished products (plates, sheets, wire rods) exceeded the growth of crude steel production. Consequently there is a drop of energy efficiencies of the whole sector in LA.

To sum up, developed regions are characterized by a shift towards less energy-intensive (high value-added) products, while in developing regions the opposite rule prevails. The reason for this complementary picture is to be explained by the differing status of resource endowment (e.g., petrochemical industry prevails in NE and pulp production in LA, respectively) as well as by differing stages of industrialization. Whether this fast growth of the primary processing industries in the South will continue or not depends on phenomena which are not analyzed within that study (changing prices for primary energy carriers, financial constraints in the South affecting industrialization policies, etc.).

Basic Sector as a Whole

The final part of the analysis concentrates on the overall impact of structural changes and technical progress on the ***basic products sector as a whole***. Two different types of time series were analyzed with regression techniques: First a series of energy intensities was calculated on the basis of energy/output ratios (by subsectors) without taking technical progress into account (Table 16), but including product-mix effects within subsectors. For each year, the overall energy intensities were simply compiled as a weighted average (with constant dollar production figures as weights) of subsectors intensity series. Secondly, to obtain total energy intensities including technical progress, average growth rates of energy saving technical progress (or better, other effects) were applied to the former "product-mix" intensities at the level of sub-sectors. The average growth rates of technical progress were taken for five sub-sectors from time series analysis of 8 developed countries presented in Chapter I.3 above. Accounting for the "best-practice-prevails"-hypothesis, growth rates of technical progress were assumed to be equal for all regions.

Table 17 presents average annual percentage rates of growth for the basic sectors ***total*** energy efficiency (including product mix and technical progress as well) and growth rates of ***structural change*** (including product mix, excluding technical progress). Growth of ***technical progress*** is simply calculated by subtraction.

Considering firstly the technical progress component, it is no wonder that annual rates are found very close from one region to another, around −2.2%, since

Table 17. Average annual percentage growth rates of energy coefficients derived from semi-logarithmic regressions (t-values in parenthesis).

Regions	Total (1)		Structural changes (2)		Technical progress (3) = (1) − (2)
	Growth rates	R^2	Growth rates	R^2	Growth rates
NA	−2.9 (39.4)	99.4	−0.5 (6.4)	80.3	−2.4
WE	−2.7 (43.7)	99.5	−0.5 (8.0)	86.4	−2.2
EE	−2.6 (50.8)	99.6	−0.6 (12.0)	93.6	−2.0
JP	-2.6 (17.6)	96.9	0.7 (4.6)	68.2	-1.9
OD	-2.1 (19.3)	97.4	-0.2* (1.4)	18.3	-2.1*
LA	-1.7 (21.6)	97.9	+0.5 (5.6)	76.4	-2.2
TA	+0.1* (0.5)	0.0	+1.9 (10.2)	91.2	-1.9*
NE	-1.0 (3.9)	61.1	+1.3 (5.4)	74.6	-2.3
IN	-2.5 (32.4)	99.1	-0.4 (5.1)	72.4	-2.1
AS	-3.9 (22.2)	98.0	-1.7 (8.8)	88.5	-2.2

* t-value indicates that the estimate does not differ significantly from zero.

exogenously assumed growth rates do not differ widely. More interesting appear the results for structural change which show product mix effects within subsectors as well as structural shifts between subsectors of the basic products sector as a whole. To detect possible structural breaks caused by oil shocks in the late 1980s, a dummy technique was used: in addition to the trend variable a dummy variable was introduced which was set to zero from 1970 to 1975 and to unity from 1976 to 1981. Non-significant estimates were found for the dummy variable. This suggests that there was no structural break in the mid-1980s and it supports that the assumption that changing energy prices did not affect industrialization policies. Therefore the identified structural changes might be considered as a long-term phenomenon rather than a short-term adjustment process to price changes.

However, the small number of observations (1976–1981) following the first oil shock casts some doubts on the validity of the test. Eventually, no dummy variable was retained and it may be noted the estimates for the growth rates of structural change were all significant (except in OD).

The range of trends due to structural change (in percent p.a.) is –0.5 to –0.7 in the first four developed regions, all negative, while no significant trend was found in the "Other Developed" region, the most natural-resource endowed in basic products. In contrast, three positive trends were found in Latin America, Sub-Saharan Africa and West Asia–North Africa, with the following values (in percent p.a.): 0.5, 1.9, and 1.3, respectively. Finally, two negative trends emerge for the Indian Sub-Continent (–0.4%) and for East and South-East Asia (–1.7%). The latter figure should be interpreted with caution since it is largely due to one sub-sector, chemical industry, with a decreasing weight, not to mention the uncertainty in estimating a trend in this sub-sector. Adding up the two components, decreasing trends in energy-intensity ranging from –2.1 to –2.9%, emerge in developed regions, with a diversified picture in developing regions: no overall trend in Sub-Saharan Africa, where the increasing intensity due to structural change compensates the decreasing intensity due to technical progress, a negative –1% trend in West Asia–North Africa, negative trends around –2% in Latin America and the Indian Sub-Continent, and a controversial figure close to –4% in East and South-East Asia.

The least that can be said on the structural change effect is that the positive changes found in Latin America, Sub-Saharan Africa, and West Asia–North Africa comply with expectations since these regions are natural resources and/or energy endowed. The negative trends found in the four largest developed regions, on the other hand, extend and confirm the analysis made in Chapter I.3, i.e., a proportion close to 25% can be attributed to structural change in the overall decrease in energy intensity. Finally, the negative results for the last two developing countries, the Indian Sub-Continent and East and South-East Asia, are more fragile, since it appears from the formar part of the analysis that an increase in energy intensity is observed in a number of sub-sectors. The negative trend of the structural change effect observed in the 1970–1981 period may therefore be reversed in the future as a result of a continuation of the industrialization policy in these areas.

It therefore looks as if major changes occurred in the 1970s in the international division of labor of primary processing industries: developed countries moved towards less energy-intensive industries, while an increased share of more energy-intensive industries was observed in developing regions. Even though it is too early to state that these changes can be considered as long-term trends, it is interesting to study, through simulations, to what extent they are likely to affect the world energy balance. This is the object of Part II.

APPENDIX I.1

Countries Selected on the Basis of Reliable Data for the Analysis of Energy Intensities by Regions

region	name	countryn
1	North Amerika	CANADA
1	North Amerika	UNITED STATES
2	Western Europe	AUSTRIA
2	Western Europe	BELGIUM
2	Western Europe	DENMARK
2	Western Europe	FINLAND
2	Western Europe	FRANCE
2	Western Europe	GERMANY, FEDERAL REPUBLIC OF
2	Western Europe	GREECE
2	Western Europe	ICELAND
2	Western Europe	IRELAND
2	Western Europe	ISRAEL
2	Western Europe	ITALY
2	Western Europe	MALTA
2	Western Europe	NETHERLANDS
2	Western Europe	NORWAY
2	Western Europe	PORTUGAL
2	Western Europe	SPAIN
2	Western Europe	SWEDEN
2	Western Europe	TURKEY
2	Western Europe	UNITED KINGDOM
2	Western Europe	YUGOSLAVIA
3	CPEs	CZECHOSLOVAKIA
3	CPEs	GERMAN DEMOCRATIC REPUBLIC
3	CPEs	HUNGARY
3	CPEs	POLAND
3	CPEs	ROMANIA
3	CPEs	USSR
4	Japan	JAPAN
5	Other developed countries	AUSTRALIA
5	Other developed countries	NEW ZEALAND
5	Other developed countries	SOUTH AFRICA
6	Latin America	ARGENTINA
6	Latin America	BARBADOS
6	Latin America	BOLIVIA
6	Latin America	BRAZIL
6	Latin America	CHILE
6	Latin America	COLOMBIA
6	Latin America	COSTA RICA
6	Latin America	DOMINICAN REPUBLIC
6	Latin America	ECUADOR
6	Latin America	EL SALVADOR
6	Latin America	GRENADA
6	Latin America	GUATEMALA
6	Latin America	HONDURAS
6	Latin America	JAMAICA
6	Latin America	MEXICO
6	Latin America	NICARAGUA
6	Latin America	PANAMA
6	Latin America	PARAGUAY
6	Latin America	PERU
6	Latin America	URUGUAY
6	Latin America	VENEZUELA

region	name	countryn
7	Tropical Africa	UNITED REPUBLIC OF CAMEROON
7	Tropical Africa	CENTRAL AFRICAN REPUBLIC
7	Tropical Africa	CONGO
7	Tropical Africa	ZAIRE
7	Tropical Africa	ETHIOPIA
7	Tropical Africa	GHANA
7	Tropical Africa	IVORY COAST
7	Tropical Africa	KENYA
7	Tropical Africa	MADAGASCAR
7	Tropical Africa	MALAWI
7	Tropical Africa	MAURITIUS
7	Tropical Africa	MOZAMBIQUE
7	Tropical Africa	NIGERIA
7	Tropical Africa	RWANDA
7	Tropical Africa	SOMALIA
7	Tropical Africa	ZIMBABWE
7	Tropical Africa	UGANDA
7	Tropical Africa	UNITED REPUBLIC OF TANZANIA
7	Tropical Africa	ZAMBIA
8	Near East	ALGERIA
8	Near East	IRAN ISLAMIC REPUBLIC
8	Near East	IRAQ
8	Near East	JORDAN
8	Near East	KUWAIT
8	Near East	LIBYAN ARAB JAMAHIRIYA
8	Near East	MOROCCO
8	Near East	SYRIAN ARAB REPUBLIC
8	Near East	TUNISIA
8	Near East	EGYPT
9	India	BANGLADESH
9	India	SRI LANKA
9	India	INDIA
9	India	PAKISTAN
10	East Asia	BURMA
10	East Asia	FIJI
10	East Asia	HONG KONG
10	East Asia	INDONESIA
10	East Asia	KOREA, REPUBLIC OF
10	East Asia	MALAYSIA
10	East Asia	MALAYSIA WEST
10	East Asia	SABAH
10	East Asia	SARAWAK
10	East Asia	MONGOLIA
10	East Asia	PHILIPPINES
10	East Asia	SINGAPORE
10	East Asia	THAILAND
11	China	CHINA

APPENDIX I.2. Shares of Regions in the World Production of Energy-Intensive Basic Materials (in percentage)

Wood pulp, sulphate and soda

341110 region	1970	1973	1978	1979	1980	1981
North Amerika	63.07	61.40	59.97	58.64	58.88	60.18
Western Europe	18.99	19.07	17.64	18.65	17.98	17.77
CPEs	5.44	5.77	7.34	6.59	6.55	6.44
Japan	8.85	9.61	8.82	9.19	8.83	7.76
Other developed countri	1.44	1.44	1.41	1.49	1.44	1.54
Latin America	1.97	2.17	4.08	4.67	5.60	5.54
Near East	0.09	0.08	0.10	0.11	0.11	0.11
India	0.12	0.25	0.44	0.43	0.42	0.41
East Asia	0.04	0.20	0.22	0.22	0.19	0.24

Wood pulp, sulphite

341113 region	1970	1973	1978	1979	1980	1981
North Amerika	34.74	32.41	33.25	33.64	34.39	36.22
Western Europe	37.39	38.23	31.94	34.04	33.15	29.90
CPEs	23.51	25.09	31.20	28.84	29.19	30.81
Japan	2.98	2.61	1.91	1.80	1.60	1.34
Other developed countri	0.25	0.27	0.35	0.34	0.40	0.40
Latin America	1.13	1.39	1.35	1.34	1.26	1.34

Zinc, unwrought

3720431

region	1970	1973	1978	1979	1980	1981
North Amerika	26.08	21.05	17.40	18.98	17.50	18.01
Western Europe	26.77	28.38	30.25	30.34	31.36	31.67
CPEs	17.94	18.24	19.48	17.98	19.16	18.25
Japan	14.21	16.52	14.20	13.73	13.17	11.72
Other developed countri	5.65	6.00	5.06	5.56	5.63	5.57
Latin America	4.16	3.97	6.09	5.93	5.86	6.91
Tropical Africa	2.53	2.37	1.66	1.47	1.44	1.71
Near East	0.00	0.00	0.50	0.49	0.56	0.62
India	0.46	0.25	1.13	1.14	0.83	0.99
East Asia	0.06	0.25	1.14	1.50	1.49	1.57
China	2.16	2.97	3.09	2.98	3.00	2.99

Aluminum, unwrought

3720221

region	1970	1973	1978	1979	1980	1981
North Amerika	48.47	42.34	39.36	38.02	38.07	38.58
Western Europe	20.41	23.31	24.84	24.99	24.85	25.34
CPEs	15.45	14.94	15.70	15.67	15.09	15.59
Japan	7.77	9.26	7.73	7.12	7.29	5.35
Other developed countri	1.79	3.16	3.57	3.54	3.49	4.03
Latin America	1.11	1.35	2.51	4.16	5.09	4.38
Tropical Africa	1.75	1.65	1.11	1.52	1.53	1.64
Near East	0.00	0.28	0.92	0.81	0.84	1.04
India	1.71	1.30	1.50	1.49	1.23	1.46
East Asia	0.16	0.14	0.15	0.15	0.14	0.12
China	1.38	2.27	2.62	2.53	2.39	2.48

Copper, refined, unwrought

3720041

region	1970	1973	1978	1979	1980	1981
North Amerika	31.40	28.50	22.04	22.15	19.88	23.06
Western Europe	14.05	13.94	14.14	14.00	14.33	12.85
CPEs	18.68	20.13	22.22	22.46	22.40	21.80
Japan	9.33	11.46	10.74	10.57	11.06	11.40
Other developed countri	2.75	2.96	3.64	3.42	3.36	3.51
Latin America	8.68	7.11	12.23	13.28	13.75	12.42
Tropical Africa	13.37	12.98	10.96	9.85	10.77	10.19
India	0.14	0.16	0.23	0.23	0.29	0.27
East Asia	0.08	0.12	0.62	0.74	0.86	1.25
China	1.52	2.63	3.19	3.30	3.30	3.24

Crude steel, ingots

371019

region	1970	1973	1978	1979	1980	1981
North Amerika	22.84	22.50	20.40	19.71	17.41	18.79
Western Europe	26.84	25.47	22.57	22.97	22.04	21.96
CPEs	25.54	24.89	30.02	28.75	30.06	30.06
Japan	16.10	17.68	14.82	15.62	16.37	15.20
Other developed countri	1.99	1.90	2.27	2.32	2.52	2.59
Latin America	2.25	2.37	2.99	3.22	3.40	3.20
Tropical Africa	0.05	0.06	0.12	0.11	0.12	0.09
Near East	0.06	0.05	0.16	0.22	0.24	0.21
India	1.12	1.10	1.48	1.42	1.41	1.63
East Asia	0.09	0.20	0.51	0.80	0.92	0.89
China	3.12	3.78	4.66	4.87	5.52	5.38

Crude steel for castings

371016

region	1970	1973	1978	1979	1980	1981
North Amerika	1.35	1.31	0.74	0.89	0.83	0.63
Western Europe	22.54	19.72	16.04	17.04	16.45	16.96
CPEs	62.07	65.33	76.62	75.45	76.01	76.37
Japan	11.14	10.43	4.54	4.50	4.69	4.14
Other developed countri	1.28	1.32	0.73	0.41	0.35	0.37
Latin America	0.41	0.50	0.28	0.70	0.68	0.59
Near East	0.81	0.99	0.73	0.72	0.71	0.65
India	0.40	0.40	0.33	0.29	0.28	0.29

Cement

369204

region	1970	1973	1978	1979	1980	1981
North Amerika	13.32	12.88	10.95	10.81	9.61	9.11
Western Europe	32.18	30.51	26.90	26.44	26.14	26.32
CPEs	23.75	22.96	23.63	22.28	22.32	21.80
Japan	10.16	11.48	10.56	10.62	10.57	10.12
Other developed countri	2.07	1.91	1.57	1.46	1.57	1.73
Latin America	5.63	6.19	7.42	7.71	8.37	8.43
Tropical Africa	0.81	0.94	0.79	0.75	0.77	0.74
Near East	2.16	2.03	2.95	3.60	3.94	4.21
India	3.02	2.70	2.95	2.69	2.64	3.04
East Asia	2.33	2.93	4.18	4.71	4.47	4.61
China	4.57	5.48	8.11	8.94	9.60	9.89

Quicklime

369201

region	1970	1973	1978	1979	1980	1981
North Amerika	13.69	16.63	18.97	19.04	17.93	14.96
Western Europe	22.88	24.05	21.51	22.28	21.68	19.16
CPEs	45.26	35.17	37.21	36.26	37.32	41.45
Japan	9.19	11.52	7.98	8.37	8.39	7.99
Other developed countri	1.43	1.87	2.29	2.01	2.50	2.80
Latin America	7.30	8.97	9.86	10.04	9.91	11.19
Tropical Africa	0.16	0.30	0.40	0.38	0.32	0.37
Near East	0.04	1.27	1.49	1.12	1.26	1.31
India	0.18	0.18	0.35	0.36	0.40	
East Asia	0.04	0.05	0.11	0.14	0.33	0.37

Nitrogenous fertilizers

351201

region	1970	1973	1978	1979	1980	1981
North Amerika	28.67	26.02	22.37	22.34	22.49	23.16
Western Europe	22.59	19.76	17.14	18.10	17.77	17.12
CPEs	28.38	29.44	29.14	26.93	26.61	27.00
Japan	6.33	5.92	3.65	3.39	2.84	2.43
Other developed countri	1.26	1.22	1.35	1.22	1.14	1.15
Latin America	2.05	2.06	2.36	2.19	2.39	2.55
Tropical Africa	0.09	0.23	0.15	0.16	0.16	0.18
Near East	0.86	1.87	1.68	1.63	1.99	1.97
India	3.04	3.71	4.38	4.44	4.45	4.54
East Asia	1.42	1.43	2.34	2.82	2.73	3.05
China	5.31	8.34	15.44	16.77	17.44	16.85

Caustic carbide

351173 region	1970	1973	1978	1979	1980	1981
North Amerika	9.12	4.06	3.79	3.89	3.78	4.48
Western Europe	28.76	20.72	14.59	14.31	14.16	11.63
CPEs	34.82	48.90	48.59	46.30	45.10	44.31
Japan	15.87	8.91	8.92	9.13	8.84	8.72
Latin America	1.03	1.61	1.93	1.96	1.93	2.11
India	0.89	0.97	1.49	1.52	1.21	1.45
East Asia	0.67	0.99	0.80	0.34	0.55	0.63
China	8.84	13.84	19.89	22.55	24.44	26.67

Caustic soda

351159 region	1970	1973	1978	1979	1980	1981
North Amerika	43.37	39.61	37.32	39.37	38.46	37.38
Western Europe	23.39	26.54	24.29	23.61	22.53	21.97
CPEs	13.33	12.79	16.59	15.40	16.09	17.00
Japan	11.24	11.58	9.32	9.29	9.81	9.37
Other developed countri	0.48	0.45	0.45	0.42	0.45	0.49
Latin America	2.09	2.41	3.57	3.45	3.62	4.08
Near East	0.16	0.08	0.19	0.20	0.20	0.17
India	1.69	1.67	2.04	1.93	1.91	2.20
East Asia	0.41	0.40	0.55	0.54	0.77	0.86
China	3.85	4.47	5.67	5.79	6.16	6.47

Ammonia

351158 region	1970	1973	1978	1979	1980	1981
North Amerika	42.82	42.02	37.70	41.28	31.45	32.81
Western Europe	33.50	37.57	33.03	28.53	19.19	15.18
CPEs	14.89	12.31	19.42	19.62	14.18	15.07
Japan	3.41	1.84	0.31	0.30	0.23	0.24
Other developed countri	0.55	0.24	0.05	0.05	0.04	0.04
Latin America	2.43	2.22	5.46	6.00	4.87	5.04
Near East	0.45	1.83	1.30	1.26	0.91	0.97
East Asia	1.95	1.98	2.73	2.96	1.90	1.77
China	27.24	28.88				

Methanol (methyl alcohol)

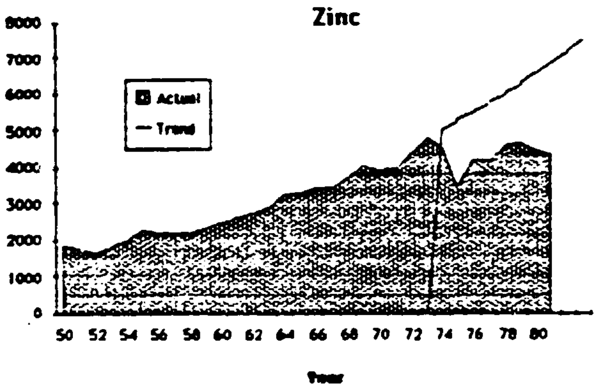
351121 region	1970	1973	1978	1979	1980	1981
North Amerika	36.47	39.58	34.58	36.98	38.02	42.79
Western Europe	24.12	22.25	17.44	17.79	14.52	12.37
CPEs	23.14	21.84	31.60	28.39	32.07	31.68
Japan	15.30	15.09	10.88	10.34	9.79	8.24
Latin America	0.32	0.33	1.23	1.92	2.03	2.02
Near East	0.00	0.00	0.57	0.52	0.50	0.44
India	0.34	0.29	0.50	0.57	0.59	0.56
East Asia	0.31	0.63	3.18	3.49	2.48	1.89

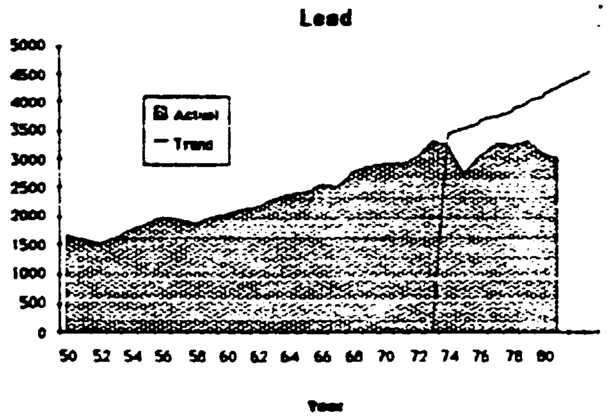
Acetylene

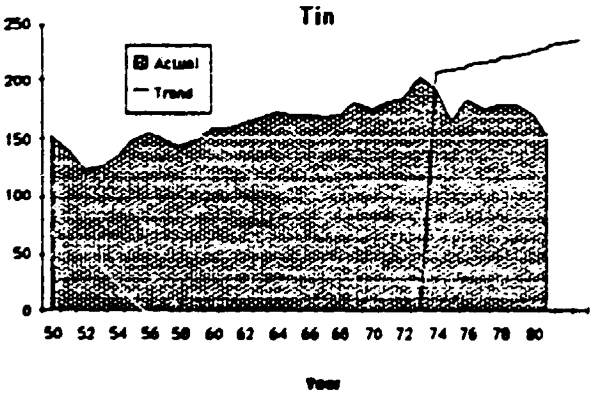
351105 region	1970	1973	1978	1979	1980	1981
North Amerika	39.26	25.22	23.73	24.56	25.08	31.45
Western Europe	50.67	58.91	50.28	50.32	50.71	39.84
CPEs	2.06	4.66	7.34	6.77	7.30	7.56
Japan	5.88	7.17	6.94	4.54	2.57	2.41
Other developed countri	0.00	0.00	0.00	0.71	0.84	1.13
Latin America	1.18	2.78	4.67	5.58	5.31	6.96
Tropical Africa	0.07	0.09	0.15	0.16	0.18	0.24
Near East	0.14	0.18	0.38	0.35	0.39	0.52
India	0.58	0.71	1.40	1.45	1.59	2.01
East Asia	0.17	0.29	5.12	5.55	6.03	7.87

APPENDIX I.3.

World Consumption of Major Metals, Actual and Trends, in Thousands of Tons, 1950 - 1982



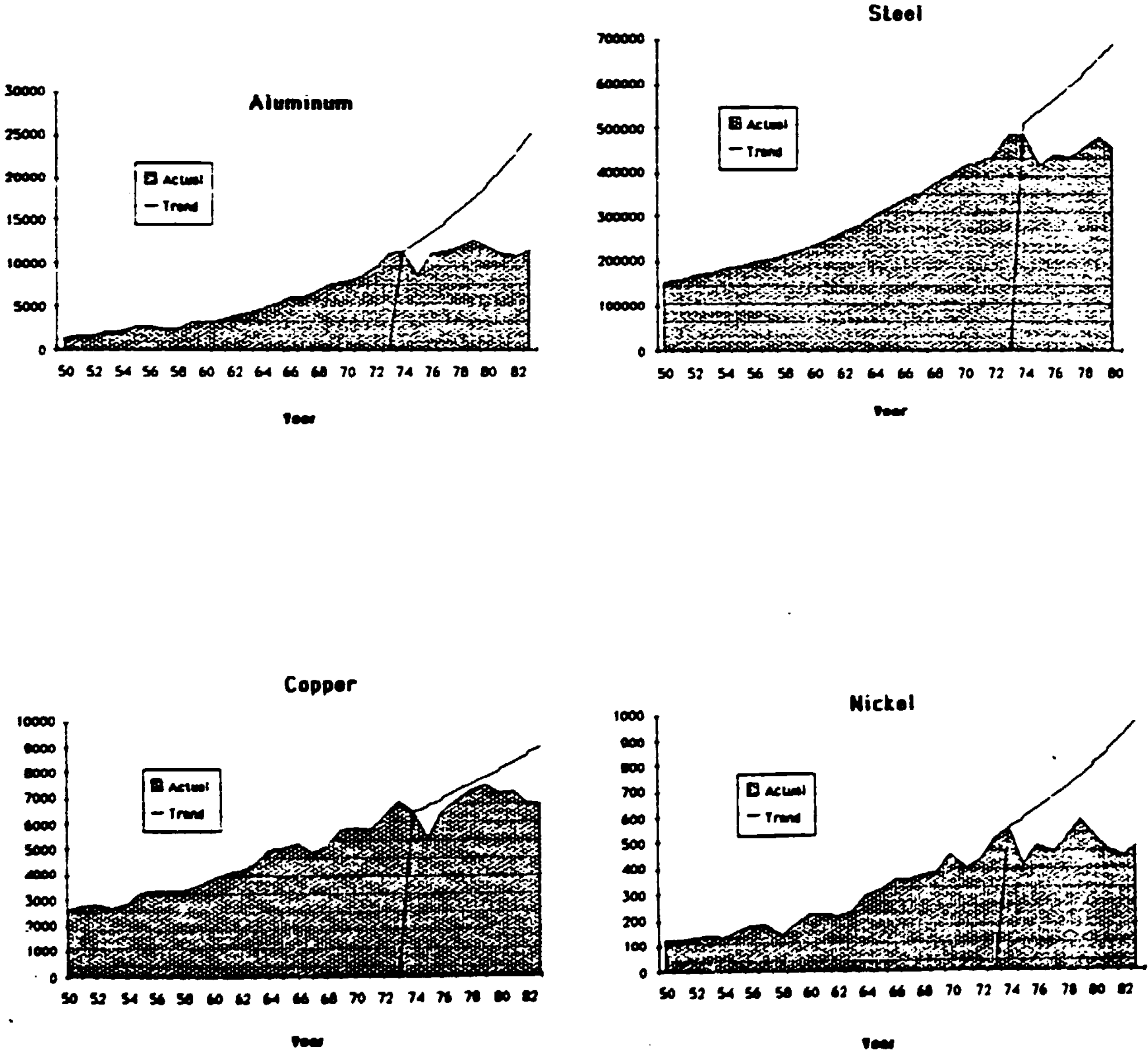




Notes: Trend figures indicate how metal consumption would have increased in the post-1973 period had growth continued at the 1950-73 rate. Steel consumption figures for a number of years between 1951 and 1972 were estimated by extrapolation.

Sources: Metallgesellschaft (annual); IISI (annual); United Nations (annual); Manners (1971).

World Consumption of Major Metals, Actual and Trends, in Thousands of Tons, 1950 -1982 (continued)



APPENDIX I.4.

ENERGY CONSUMPTION BY DEVELOPING COUNTRIES

Thailand, 764, th. mtoe

Years	Final Energy Consumption		Total Primary Energy
	Industry	Total	
1970	1579	5063	6285
1971	1625	5953	7551
1972	2121	6930	7936
1973	2344	7804	9567
1974	2300	7664	9173
1975	2581	8046	9924
1976	3071	9164	11073
1977	3296	9672	13065

Nigeria, 566, th, mtoe

Final Energy Consumption		Total Primary Energy
Industry	Total	
383	15354	15652
580	15954	16527
584	16775	17373
708	18295	19131
899	19416	20130
1558	21336	22037
1197	20977	21729
1156	22427	23754

Mexico, 484, th. mtoe

Years	Final Energy Consumption		Total Primary Energy
	Industry	Total	
1970	17770	40993	49089
1971	18865	42310	50805
1972	21164	46002	55468
1973	23201	49329	60176
1974	25673	53740	65045
1975	27436	55556	69270
1976	27549	57818	73131
1977	35226	66872	78816

Korea, 410, th. mtoe

Final Energy Consumption		Total Primary Energy
Industry	Total	
1267	17069	19487
1339	18828	21200
1327	16475	21790
1662	19908	24759
2189	20589	25266
2464	23432	27952
2727	24334	30615
3029	27596	34460

Kenya, 404, th. mtoe

Years	Final Energy Consumption		Total Primary Energy
	Industry	Total	
1970	203	3437	3671
1971	242	3634	3896
1972	185	3617	3918
1973	276	4290	4580
1974	295	4114	4439
1975	302	4127	4434
1976	352	4034	4520
1977	375	4026	4404

Jamaica, 388, th. mtoe

Final Energy Consumption		Total Primary Energy
Industry	Total	
838	1683	1881
1018	1985	2211
no reliable data	2059	2309
	2675	2943
	2508	2775
	2603	2886
	2609	2906
	2562	2897

New Zealand, 554, mill. mtoe

Years	Final Energy Consumption		Total Primary Energy
	Industry	Total	
1971	1.42	5.55	8.35
1972	1.64	6.13	9.31
1973	1.77	6.52	9.59
1974	2.27	6.52	10.08
1975	2.51	6.88	10.59
1976	2.52	7.14	10.94
1977	2.65	7.33	11.42
1978	2.55	7.19	11.36
1979	2.63	7.13	11.15
1980	2.49	7.66	11.69
1981	2.51	7.66	11.8

Australia, 036, mill. mtoe

Final Energy Consumption		Total Primary Energy
Industry	Total	
15.43	33.25	52.25
14.89	33.78	53.65
18.18	39.86	58.25
20.67	42.97	62.13
19.27	42.42	63.29
20.64	43.89	67.47
20.45	45.51	68.86
19.69	50.54	72.40
20.11	47.96	76.92
20.57	48.35	76.22
19.92	49.09	77.21

Japan, 392, mill. mtoe

Years	Final Energy Consumption		Total
	Industry	Total	Primary Energy
1970			
1971	125.3	211.7	293.2
1972	131.6	226.2	312.4
1973	145.1	249.7	340.4
1974	139.5	243.6	341.6
1975	126.6	235.7	328.2
1976	148.8	258.3	348.7
1977	146.4	260.2	352.7
1978	148.5	269.6	362.3
1979	152.4	293.0	377.0
1980	139.4	261.3	365.1
1981	132.4	254.5	362.1

Indonesia, 360, th. mtoe

Years	Final Energy Consumption		Total
	Industry	Total	Primary Energy
1970	434	36394	38476
1971	1210	36621	40665
1972	661	38555	40375
1973	627	40481	42765
1974	794	44570	45162
1975	1011	47269	48238
1976	1127	54893	54383
1977	1255	63944	72489

Iran, 364, th. mtoe

Final Energy Consumption		Total
Industry	Total	Primary Energy
10335	19599	21982
9222	19652	23079
8986	20576	22588
10221	23995	28063
11739	27834	33598
10981	30642	34746
11765	32989	38458
18860	42610	48803

Region 9, India, 356, th. mtoe

Final Energy Consumption		Total
Industry	Total	Primary Energy
30193	82408	98848
30217	83678	101067
32509	89102	107867
33922	91527	111733
36709	94252	114252
39886	98678	123662
40387	102814	129014

Region 8, Egypt, 818, th. mtoe

Years	Final Energy Consumption		Total Primary Energy
	Industry	Total	
1970	895	5777	7679
1971	939	6719	8572
1972	908	7475	9348
1973	888	6754	8790
1974	957	7654	9797
1975	1219	8623	11220
1976	1347	11191	13621
1977	1454	11908	13900

Colombia, 170, th. mtoe

Final Energy Consumption		Total Primary Energy
Industry	Total	
497	13406	16376
565	14140	16835
472	14596	17950
487	14813	18321
901	15440	18996
983	14714	19429
1062	15054	20008
1061	16745	20462

Region 1, North America, , mill. mtoe

Years	Final Energy Consumption		Total Primary Energy
	Industry	Total	
1971	414.55	1338.43	1735.96
1972	452.56	1423.48	1843.65
1973	457.68	1426.36	1901.0
1974	447.30	1392.4	1915
1975	402.2	1341.7	1869
1976	438.7	1428.6	1974
1977	430	1465	2029
1978	438	1510	2100
1979	450.3	1529	2097
1980	431.4	1464	2034
1981	416.8	1422	1993

Western Europe, , mill. mtoe

Final Energy Consumption		Total Primary Energy
Industry	Total	
336.1	797.4	1075
347.5	839.5	1122
376.5	906.4	1200.5
372.9	873.7	1179
335.0	842.5	1135.0
348.9	882	1193
343.6	885	1205
342.4	909	1238
362.9	949	1290
339	904	1251
318	869	1218

Source: Energy Balances of OECD Countries,
Paris, 1983

Brazil, 076, th. mtoe

Years	Final Energy Consumption		Total Primary Energy
	Industry	Total	
1970	12779	53176	65197
1971	14246	56340	70114
1972	16539	61889	77066
1973	19693	68161	89616
1974	21081	74735	95229
1975	21690	78097	97734
1976	24369	84717	107167
1977	-"-	-"-	-"-

Algeria, Region 8, 012, th. mtoe

Years	Final Energy Consumption		Total Primary Energy
	Industry	Total	
1970	579	3312	3679
1971	560	3433	3778
1972	500	5657	5888
1973	513	5190	6483
1974	513	5741	6584
1975	629	5993	7497
1976	768	7694	9930
1977	912	20729	21563

Argentia, 032, th. mtoe

Final Energy Consumption		Total Primary Energy
Industry	Total	
6400	24049	33156
6395	25234	35276
6243	25137	35947
6972	26881	38307
7249	27457	39819
8493	28310	41185
9620	29265	42526
9883	29209	43403

Venzuela, 862, th. mtoe

Final Energy Consumption		Total Primary Energy
Industry	Total	
5438	13345	21119
5233	13587	22129
5912	15053	17676
7816	17521	25667
7827	18516	27654
2729	19179	26166
8068	20681	19934
8489	22051	30603

PART II: UNITAD SCENARIOS

This part deals with forward-looking explorations of energy issues based on the analysis achieved so far. It is divided into four chapters, the first briefly mentions relevant methodological aspects of the UNITAD model, which is a UNIDO model built up for long-term exploration purposes. The second follows directly from Part I and concentrates on energy issues. The macroeconomic framework is then justified and analyzed in the medium-term (1984–1990) in Chapter II.3 and in the long-term (1990–2000) in Chapter II.4. Brief policy conclusions follow.

II.1 SUMMARY FEATURES AND DATA BASE OF THE UNITAD MODEL

No attempt is made here to describe the UNITAD model, except to recall a few relevant features. It is composed of eleven regional models interacting among each other through a series of seven trade matrices, by commodity groups – including one governing trade in energy material and another, trade in intermediary products, i.e., the outcome of the basic product sector. In each regional model, demand and supply balance by producing sector is achieved through an 8*8 Input–Output core. Intermediary consumptions of energy can be changed by exogenous multiplyers affecting the "input" matrix, and this was done in this exercise to the energy coefficient of the basic product sector only. Final consumption is endogenously generated by a linear expenditure model sensitive to price and income changes. The energy price, which is produced by the dual Input–Output model, can be changed by a coefficient which simulates the rent effect of an OPEC policy. It was therefore easy to incorporate in the model the energy price forecasts issued by IIASA (see Annex 4).

An original feature of the model is the possibility of introducing supply constraints in any sector. This was achieved in this exercise in two sectors, agriculture and energy. Upper bound limits of agricultural growth rates were introduced in some regions (Sub-Saharan Africa and West Africa) to simulate the low growth rates observed in these regions for various reasons, some of climatic origin, others due to a neglect of agriculture through a variety of policies (e.g., price distorsions).

The upper bound limits of the energy sector are meant to simulate constraints in natural resources. For this purpose, the energy sector is subdivided into four sub-sectors, namely liquid and gas fuels, utilities, solid fuels, and refineries. The upper bound limits were essentially applied to liquid, gas and solid fuels (see below).

The model computes aggregates at constant and current prices. The former are supposed to convey trends of physical units, but two steps further were achieved in this exercise, i.e., converting constant prices aggregates into physical units, and secondly, deriving primary energy units. In order to do this, constant prices aggregates relating to gross production figures, by energy sub-sector, were divided by the dollar price of tons of oil equivalent (1970 dollars/toe) in 1975, i.e., the base year period. The energy row of the balance of goods and services was thus made to reflect the current output mix in terms of sub-sectors.

Primary energy units were derived by adding up the endogenous figures of liquid/gas and solid fuels and an exogenous term for primary electricity (hydroelectric, nuclear and miscellaneous electricity generation).

The data base of the model was updated and enlarged in several respects. Firstly, energy input and value-added coefficients of the base year (1975) were updated to 1980 using both the results of the historical analysis in Part I and a new set of input/output tables supplied by UNIDO. The difficulty was to express new figures in 1970 prices. The first step was to apply the energy-saving trends derived from Part I over 1970–80, to original 1970 energy input of the "Basic Products" column. The ratio of the energy input in 1980 (at 1980 price) to the derived 1980 input at 1970 prices yielded the energy price, which was then used to deflate energy inputs in other sectors of the new 1980 tables.

The other major change in the data base was the maximum energy supply for fossile fuels in 1990 and 2000 and the exogenous estimate for primary electricity for the same years. Using three different sources (IIASA estimates in Annex 2, UN, ECE and International Energy Agency of OECD), the following estimates were entered by region (Table 18).

As can be seen, the South ratio of world primary resources in liquid and gas fuels is assumed to continuously grow up from 48% in 1975 to 51% in year 2000.

Table 18. Upper bound limits of energy primary units, by region (million tons of oil equivalent).

	1975			1990			2000		
	Liquid & gas	Solid	Electricity	Liquid & gas	Solid	Electricity	Liquid & gas	Solid	Electricity
North America	1162	437	55	986	701	354	986	958	600
Western Europe	169	230	109	300	260	295	280	260	525
Eastern Europe	708	558	44	1306	790	196	1527	996	338
Japan	4	16	23	7	12	75	7	10	135
Other developed	30	96	8	48	235	16	48	348	30
Latin America	328	10	31	547	40	90	547	62	208
Sub-Saharan Africa	125	3	6	162	8	10	162	10	24
W. Asia–N. Africa	1300	1	4	1600	3	18	1800	3	37
Indian Sub-C.	17	85	10	47	85	28	47	125	58
East & S.-E. Asia	102	13	4	236	30	26	236	47	55
CPE, Asia	69	364	15	148	655	55	215	980	116
World	4014	1813	309	5387	2819	1163	5855	3799	2126
of which									
North	2073	1337	239	2647	1998	936	2848	2572	1628
South	1941	476	70	2740	821	227	3007	1227	498

* Primary electricity (hydro, nuclear, miscellaneous) is measured as the fossile fuel input equivalent used in thermal power station.

Total primary units however hardly change in proportion between North and South (around 60% in North as against 40% in South) on account of the progressive shift, in the North, from liquid and gas fuels to solid fuels and primary electricity. (This comparison is valid since energy units of primary electricity were computed, according to OECD practice, in terms of fossile fuel input equivalent used in thermal power stations.) This analysis should not however be taken too far since many oil and gas deposits can be discovered and put into operation between today and year 2000. In the table, year 2000 estimates of liquid and gas fuels are on the cautious side.

II.2 THE ENERGY BALANCE IN THE SCENARIOS

The potential impact of findings on energy savings in the basic product sector on energy balances were tested in simulations carried out with the use of the UNITAD model. Simulations were designed so as to allow only one shock to the system at one time and to do this, it was considered preferable to operate on the period extending from 1990 to 2000 rather than in the 80's where conditions are likely to be influenced by many events. Following a base-line scenario from 1980 to 1990 (described later), three different simulations (denominated A,B,C) were built up for a ten-year period.

- Simulation A is based on an assumption that no permanent structural changes towards less energy-intensive industries take place in the Basic Products sector of developed countries. So energy input coefficients in developed countries were modified by a multiplyer reflecting only the continuation of trends in technological progress. ***No such trends were applied, by convention, to the basic product sector of developing regions in this and other simulations.***
- In simulation B, two sets of exogenous assumptions were introduced: On the industrial side, developed countries specialize in less intensive processing industries (input coefficients are affected by a multiplyer reflecting both the technological progress trends and the output-mix effect described in Chapter I.6); on the trade side, an international division of labor progressively develops in all manufacturing goods: developing regions sell more intermediary products (produced in the basic products sector) both to developed countries and on their own markets; other commodity markets also benefit by trade liberalization but to a minor extent as compared to intermediary products. In this experiment, all other parameters, and in particular GDP growth, were kept at the same level as in simulation A, so as to derive the primary order effects of the assumptions.
- Finally in simulation C, a 1-percentage point of annual growth rate was added up in all developing regions, in order to derive marginal growth elasticities for comparison purposes.

The result of the experiments firstly confirm expectations: when considering the industrial uses of energy, total primary units consumed in the South increase in simulation B, compared to A, while the opposite is observed in developed regions. But one interesting result emerges: the total world primary use of energy in industrial sectors decreases, and so does total world energy consumption; this reflects the fact that all indirect effects of the North–South substitution in the basic products sector, when permeating other sectors of developing economies, give rise to less energy consumption than in the North (e.g., income accruing to households is spent in much smaller energy/capita figures).

Table 19. Industrial consumption of energy in the world (primary units in millions of toe).

Regions	1990	2000 simulation		
		A	B	C
Developed Market Economies	3687	5593	5466	5390
Eastern Europe	1501	1858	1831	1874
Developing Market Economies	1012	1485	1547	1769
CPE, Asia	557	749	751	827
World	6757	9685	9595	9860

As can be seen in the table, there is a shift of –127 Mtoe from simulations A to B in developed market economies, matched, but not compensated by a +62 Mtoe shift in developing market economies. Together with shifts in the same direction in Centrally Planned economies, the end result is a net decrease of 90 Mtoe in the world at large. These figures seem small in absolute terms or in relative terms (around 1% of the world total). But it should be remembered that no assumptions on energy-saving trends were applied to developing regions, for clarity purpose. But even a small annual energy-saving trend in the basic sector of developing regions will make the world balance significantly lower. For example, a –1% annual trend, equal to one half of what was applied to developed regions, would affect by a multiplyer of 0.90 the energy consumption of developing regions in simulations A, B, and C. This, it may be objected, should not affect the difference between simulations B and A, unless we have reasons to believe that more energy savings take place in one of them. The argument is indeed that the introduction of energy-saving technology should go parallel to the creation of new capacity in the sector, and, as will be seen, the growth of capacity is much higher in simulation B than in A, since we simulate in the former scenario an assumption of rapid North–South redeployment of the industry. This 1% change in the world total, small as it is, is therefore a clear indication of the direction of the move. Slightly higher figures obtain when measuring total energy consumption (not shown in the table), i.e., a 1.5% decrease in total consumption.

The growth of the basic products sector over the ten-year period, can be illustrated by the following figures (Table 20).

Table 20. Growth of the basic products sector, 1990–2000 (annual growth rates, elasticity to GDP between brackets).

	Simulations					
	A		B		C[1]	
Developed countries	4.0	(1.2)	3.8	(1.1)	.	
Developing countries	8.4	(1.3)	9.2	(1.4)	.	
of which						
Latin America	9.5	(1.2)	10.4	(1.3)	.	(1.0)
Sub-Saharan Africa	10.9	(2.6)	12.1	(2.9)	.	(.2)
West Asia–North Africa	15.5	(1.8)	12.1	(2.9)	.	(.95)
Indian Sub-Continent	5.2	(1.1)	5.8	(1.2)	.	(1.2)
East & South-East Asia	10.1	(1.6)	11.6	(1.8)	.	(.8)

[1] marginal growth elasticity to GDP.

In all developing regions, the growth figures and the GDP elasticities are higher in simulation B as compared to A. For developing countries, the two elasticity figures are 1.4 and 1.2 respectively, with, as expected, the reverse ranking order in developed regions, namely 1.1 versus 1.2 respectively. Similarly, when considering total manufacturing (not shown in the table), the following comparison can be made between GDP elasticities of simulation B versus A: developing regions 1.3 versus 1.2, developed regions 1.0 versus 1.1.

As a consequence, the Value-Added of manufacturing in market developing regions over the world total would rise from 9% in year 1990 (14% with CPE, Asia) to 14% of world total (20% if CPE, Asia is included) in simulation B, as against 13% in simulation A (19% with CPE, Asia).

Why should the basic products sectors grow faster than other manufacturing sectors? A first answer is suggested by the successful industrialization strategy followed in the 70s and the 80s by most advanced developing regions, such as Brazil, Korea, and others. The making of textiles or metal goods in the 60s was followed in these countries by the development of upstream industries making textile fibers or iron and steel. Soon, however, another objective was set: to produce equipment goods, be it to save imports of machinery or to upgrade exports from low to high value-added. A major point here, is that the key to the control of technology in many equipment goods is largely in the making of high quality steel or ferro-alloys – hence the race towards the building of a modern Iron and Steel Industry, an objective by and large achieved today by Brazil, Korea, and Mexico, to quote the top racers.

Another justification, though,seems to lie in the natural resource endowment of many countries of the South – especially oil producers, which aim at increasing the value added of their exports. Hence, in these countries, a fast expansion of petrochemical industries, a successful story already for Mexico or Saudi Arabia – and soon a major source of structural change in the world trade of chemical products. There is obviously, in the latter industrialization strategy, a major difference with the first, in that a natural resources endowment induces a high export/output ratio, as will be the case for the petrochemical industry of the Gulf countries. In contrast, the iron and steel industries and the textile fiber industries are essentially oriented towards the home market – even if final products (steel intensive equipment goods such as ships and cars – or textiles and clothes) are largely meant for exports. The simulation achieved in this report is reproducing both types of strategies through a correct capturing of the trends of Input coefficients.

II.3 THE BASE-LINE MEDIUM-TERM SCENARIO: SOME MACROECONOMIC ISSUES

The international environment in 1984 does not look most encouraging to Developing Regions and more generally to the international economy, even if some recovery signs are seen here and there. But what makes the picture appear gloomy is the number of deeply rooted disequilibria which threaten the future. Among some: the magnitude of unemployment ratios and of budget deficits in developed regions, the vagaries of international monetary and financial markets, with absurd peak values for major currencies parity and interest rates, and, not least, the overwhelming weight of the adjustment imposed on debtor countries. In order to evaluate the impact of such an environment on the international economy, a no-change assumption was imposed on major international parameters for the period 1984–1990.

In the first place, no decline was assumed for real interest rates – which were set at a high plateau around 7–8% – with two major consequences: firstly, a severe outlook for corporation profits, and therefore a low investment level in the North. Secondly, a heavy reimbursement burden to indebted economies. No major change was similarly introduced on the dollar parity, with, as a result, a deficit in the US trade balance remaining at a high level – above 100 billion dollars – for the rest of the decade. Other assumptions refer to the international prices of major commodity groups. Firstly, energy prices would slowly recover from their minimum level, expected to be reached in 1985, and would, in accordance with IIASA forecast, reach in 1990 a level around 80% of year 1980 level (in real terms). Prices of Agricultural Goods and raw materials, similarly, would recover from the depressed 1983–1984 levels (UNCTAD Index 74 and 75 respectively, base 1980 = 100) and reach in 1990 more satisfactory nominal prices, yet relatively low in real terms.

On energy consumption, as was already stated, the energy-saving coefficients found in this study in the 70s for the primary processing industries (steel and non-ferrous metals, basic chemistry) were repeated for the 1980–90 period.

The outstanding debt of developing economies was not allowed to grow in real terms, which means, in nominal terms, a growth of 4–5% per annum, i.e., the assumed inflation rate of the dollar. This, however, was only imposed on the sum total of the outstanding debt, leaving room for large differences among regions.

Table 21. GDP growth rates in the 1970s and the 1980s (% p.a.).

Regions	1970–80	1980–90	of which: 1984–90
North America	3.0	2.6	2.5
Western Europe	3.0	2.2	2.6
Eastern Europe	4.6	3.5	3.7
Japan	4.9	4.0	4.2
Other developed	3.0	2.7	2.6
Latin America	5.3	1.9	3.1
Sub-Saharan Africa	4.1	0.4	0.9
West Asia–North Africa	4.9	3.9	5.2
Indian Sub-Continent	3.6	4.9	4.6
East Asia	7.7	5.6	5.6
China and other CPE's, Asia	6.3	5.0	4.6
	SUMMARY		
(A) Developed Market E's (DDM)	3.2	2.6	2.9
(B) Developing Market E's (DGM)	5.3	3.3	4.1
(C) World (excluding CPE's)	3.5	2.7	3.1
Ratio (B/A)	(1.7)	(1.3)	(1.4)

Source: Observed figures from 1975 up to 1984 and UNITAD model thereupon.

The first series of results to be reported is the set of growth rates for 1984–90 decade (see Table 21). As can be seen from the last column of Table 21, on the right side, the world economy is expected to grow at an annual rate of 3.1% up to the end of the decade, with Japan (4.2% p.a.) taking the lead in the recovery from 1985 onward, following the American recovery in 1984. Altogether, with an annual growth of 2.9% p.a., the developed economies would not attain the growth path of the 70s (3.2% p.a.), thus – ceteris paribus – leaving no hope to achieve a full-employment target. Developing countries would be even farther away from their past performances, with a 4.1% p.a. annual growth rate. The growth ratio between developing and developed market economies (1.4) would therefore remain significantly below the ratio achieved in the 70s (1.7). Yet this ratio is higher than 1 for the 1984–90 period, which was not the case for the 1980–84 period.

Altogether, if looking at the 1980–90 decade, the scenario is merely reproducing the type of low growth equilibrium which can, at best, be generated by the present international environment. It is worth noting that the only regions to emerge with a significant growth are those of South and East Asia, whether developed or developing, market oriented or centrally planned, i.e., in order of decreasing growth rates (in percent p.a.) for 1970–80: East Asia (5.6), China (5), Indian Sub-Continent (4.9), and Japan (4.0).

At the other extreme, Africa South of Sahara (0.4% p.a.) and Latin America (1.9% p.a.) are handicapped by their debt burden, and have decreasing per capita growth rates – a desperate finding for the weakest population groups. However, from 1984 onward, Latin America would achieve a 3.1% p.a. GDP growth rate, but Africa South of Sahara would not be expected to go beyond a low GDP 0.9% rate, a growth of output far below the population growth rate (3% p.a.) partly due to the low growth rate of African agriculture and partly to the debt burden. To say the least, this result, which looks highly plausible, fully justifies the special Aid Programmes now discussed in various UN Agencies.

The major conclusion is therefore clear, i.e., the present growth pattern of the world economy, even taking into account the vigorous American recovery and the partial recovery of Japan and Europe in the mid-eighties, tends to perpetuate the prevailing disequilibria: massive unemployment in most regions, and hardly any solution to the debt problem. But is there any plausible alternative solution available to policy makers? This is explored in the longer-term scenario.

II.4 THE BASE-LINE 1990–2000 SIMULATION: MACROECONOMIC IMPLICATIONS

In order to improve on the growth pattern of the eighties, new assumptions were made to prevail in the 90s, essentially in the trade and financial areas. A progressive restoration of free trade was introduced in manufactures. This does not go as far implying that protectionist barriers were fully dismantled (an assumption left for simulation B already studied), but simply that efforts were made by developed economies to accommodate a continuation of penetration of goods from developing economies on a trend basis. On the financial side, interest rates between 2 and 3% were introduced, as well as a few years extension of the maturity periods for debts. At the same time, all developing regions were requested to achieve a debt-service ratio (relative to their exports) lower than 20 per cent.

Supply conditions were set for two natural resources based sectors, i.e., agriculture and energy. The growth rate of primary energy units was constrained in every region not to exceed specific values amounting to a maximum growth of 2.6% p.a. for the world as a whole from 1975 to 2000.

On the agriculture side, upper limit growth rates higher than in the 80s were set for Sub-Sahara Africa (2.5% p.a. instead of 2% p.a.) and West Asia and North Africa (2.8% p.a. instead of 2% p.a.). This implies not only better weather conditions but, as supported by a large consensus among International Organizations, a sound price policy and a vigorous agricultural development effort.

The growth of the North, exogenously set in the model, was deliberately taken at a level not much higher than in the 80s, so as to remain on the cautious side. More precisely, developed market economies were expected to grow at a 3.1% rate per annum, while Eastern Europe, benefitting from better energy prices, more liberal trade conditions, and successful economic reforms, grew at a 4.5 % annual rate.

There is one more policy assumption, perhaps the most powerful contribution to the solution of the debt problem. The low growth rate of the North, if matched with a liberal trade management, is likely to result in large trade deficits with developed countries. Full acceptance of such deficits was assumed on behalf of governments of developed countries over the whole decade. The implication is that little feedback of the growth of the South was allowed to permeate economies of the North. Provocative as this may seem, it is far more rational than the present situation when high interest financial rates inflate the debt burden, while protectionism prevent debtors to gain export earnings.

The growth assumptions for the North and growth results for the South are shown below (see Table 22). As can be seen, the developing market economies reach in this scenario an exceptionally high growth rate of 6.9% p.a., of the same order as that set for the development decade, but with a large spread among regions:

Table 22. GDP annual growth rates from 1990 to 2000.

		Base-line scenario 1980s	Base-line scenario 1990s
(A)	Developed Market E's (DDM)	2.6	3.1
(B)	Eastern Europe	3.5	4.5
(C)	Developing Market E's (DGM)	3.3	6.9
(D)	CPE, Asia	5.0	5.0
(E)	DDM + DGM	2.7	3.9
(F)	(C/A) ratio	(1.3)	(2.3)
(G)	World	3.2	4.1

The ranking of growth rates by region may seem surprising, especially the fact that the growth leaders, in the 1990s, are West Asia and Latin America and no longer South and East Asia (Table 23). The explanation lies in the rise in energy prices, along the lines of IIASA forecast in Annex 4. The higher the energy price, the higher the growth of major oil exporting countries, which are assumed to be located in West-Asia–North Africa and Latin America as they are now.

Table 23. Regional GDP growth pattern in the 1990s (% p.a.).

Latin America:	7.8	Indian Sub-Continent:	5.0
Sub-Sahara Africa:	4.2	East and South-East Asia:	6.5
West Asia–North Africa:	8.5	CPE,Asia:	5.0

In Table 22, the growth ratio between South and North (2.3) appears at first glance relatively high as compared to the exceptionally low figures of 1.3 of the 80s. This is direct consequence of trade conditions simulated here – i.e., the further penetration of manufactures from the South into the North. As expected, the South, thanks to this growth differential is able to repay part of its debts. As already noted, this implies an acceptance, by many countries in the North, of a "structural" trade deficit vis a vis debtor countries, over a decade or more. Even if this is not usual by historical standards, it can be taken as measuring the time period (several decades for Sub-Saharan Africa) required by the South to repay their debts. Needless to say, there are many alternative financial arrangements which might be worked out to shorten repayment periods but this was left outside the scope of the study.

The trade in manufactures is illustrated in Table 24.

Table 24. Trade in manufactures (in percentage of world).

	1990	2000
Developed Regions	89.7	79.4
Developing Regions	10.3	20.6
of which		
Latin America	2.4	5.7
Sub-Saharan Africa	0.4	0.6
West Asia	0.3	1.7
Indian Sub-Continent	0.6	1.3
East Asia	6.0	10.8
CPE's Asia	0.6	0.5

The share of the South in world exports doubles up from 1990 to 2000, to reach at the end of the decade a little over one fifth. Out of this share, East Asia alone makes more than 50% total manufactures exports of the South, and Latin America, another 28%. Intermediary products, in manufactures exports, becomes the first commodity group (around one third), followed by equipment and machinery (30%).

However, the proportion of exports of intermediary products on total manufactures export is highly variable from region to region. The following figures are supplied by the model for the year 2000 (Table 25).

Table 25. Proportion of intermediary products on total manufactures exports in year 2000, by region (in %).

Latin America:	28.3	Indian Sub-Continent:	22.5
Sub-Saharan Africa:	84.4	East & South-East Asia:	29.8
West Asia–North Africa:	58.9	Centrally Planned Asia:	4.4

This cast of figures is highly suggestive. High proportions of exports of intermediary products as found in Africa and West-Asia, two natural resource-endowed regions, while much lower proportions between 20 and 30% are found in the most industrialized regions of the South. This suggests again two patterns of international division of labor. The first would be largely based on "Ricardian" trade, i.e., on natural resource endowment, whereas, in the other, intermediary products would be domestically processed and exported in the form of finished goods. This is already the case for new industrializing countries in the 1980s but is likely to develop on a larger front in the three regions identified by the model, Latin America, South Asia and South-East Asia.

General Conclusions

Two major policy conclusions emerge from these simulations. On the macroeconomic policy side, this study illustrates one possibility of achieving a much better world equilibrium than is likely to result from the continuation of present trends. With a more liberal management of world trade – even allowing for a long adjustment period for the North – and a political will to solve the indebtedness problem, much higher growth rates can be achieved in developing areas and (although it was not explored here) in developed countries.

At the same time, as considered in this study, such higher growth of the world economy would permit a fast development of energy and capital intensive industries in the South belonging to what is called here the basic products or the primary processing sector. This development, it was shown, which conform to a rational international division of labor in the energy-endowed South, would comply with reasonable assumptions on the likely development of the energy sector. At any rate, the high growth of energy consumption in the South resulting from the development of the primary processing sector would altogether alleviate world energy demand (and therefore lower energy prices) as compared with a continuation of the present concentration of the industry in the North.

To sum up, industrial redeployment in the primary processing industry not only tends to achieve a better South–North balance of the manufacturing sector along policy lines advocated by UNIDO, but it also contributes to an optimal use of scarce energy resources at the world level.

ANNEX 1. Terms of Reference

The work will be carried out in the following areas:

(a) A historical analysis of energy intensities. This will review changes in such intensities especially with respect to changes in price for developed and as far as possible for developing countries, and for different branches of economies, especially for industrial branches.

(b) A review of present estimates of energy resources by type and by region. This review would be directed towards preparing estimates of future availabilities of energy supplies for the years 1990 and 2000, in non-renewable energy sources in the years mentioned. The implications for investment costs associated with such levels should also be examined.

(c) The incorporation of conclusions from the above work in scenarios of industrial development to the year 2000. Prepared with the aid of the UNITAD model, these scenarios are to be refined by the inclusion of material from the study of energy intensities and of supply, including as far as possible an examination of the trade and structural effects implied by the scenarios.

(d) Derivation of conclusions on the policy implications of the scenarios, especially with respect to (i) the implications for industrialization of the developing countries; and (ii) co-operation possibilities (North-South and South-South) in the energy field.

Annex 2.

ESTIMATES OF THE MAXIMUM POTENTIAL OUTPUT OF THE ENERGY SECTOR

Modeling the supply and demand of exhaustible resources without first defining the maximum availability of these resources would mean that only very short-term conclusions could be drawn. Therefore most modeling systems designed for projections of "energy futures" are based on estimates of ultimately recoverable resources of primary energy. The scarcity of a product at any given time is then not only defined by its absolute availability but also by its production cost.

The IIASA energy modeling system is based on estimates of ultimately recoverable resources of primary energy broken down by cost categories for seven world regions (Table 2-1). Table 2-2 summarizes these estimates. Given these estimates of *total* energy resource availability, the maximum potential outputs from each source are then estimated. This not only calls for consideration of geological potentials but also requires assumptions regarding economic, technical, and environmental constraints. These include build-up constraints, reflecting the temporal and financial factors involved in introducing new capacity, as well as environmental constraints (e.g. the wastes that result from oil-shale production and the lack of adequate water supplies both strongly restrict the development of this resource). On the basis of *these* constraints, maximum potential production profiles are estimated. The estimates used in the IIASA energy-supply model MESSAGE (Model for Energy Supply Systems And their General Environmental impact) are presented in Table 2-3. Since for some energy carriers in some particular regions no constraints are built into MESSAGE, and also in order to evaluate the given limits, projected outputs (after balancing supply and demand within the IIASA model system) are presented in parentheses. In the case of electricity and heat generation, projected installed capacities are given instead of projected outputs; these capacities (approximately 50% of output of electricity generation), shown in parentheses, may serve as estimates of the upper limits on production.

Table 2-1. The seven world regions used in the IIASA energy modeling system (Häfele 1981).

Region	Areas included	Region	Areas included
I	North America (Canada, United States)	V	Africa (except Northern Africa and South Africa), South and Southeast Asia
II	Soviet Union and Eastern Europe	VI	Middle East and Northern Africa
III	Western Europe, Japan, Australia, New Zealand, South Africa, Israel	VII	China and Centrally Planned Asian Countries
IV	Latin America		

Table 2-2. Summary of estimates of ultimately recoverable resources by cost category.

Resource	Coal[a] (TWyr)		Oil (TWyr)			Natural Gas (TWyr)			Uranium (TWyr)	
Cost Category[b]	1	2	1	2	3	1	2	3	1	2
Region										
I	174	232	23	26	125	34	40	29	35	27
II	136	448	37	45	69	66	51	31	ne	75
III	93	151	17	3	21	19	5	14	14	38
IV	10	11	19	81	110	17	12	14	1	64
V	55	52	25	5	33	16	10	14	6	95
VI	<1	<1	132	27	ne	108	10	14	1	27
VII	92	124	11	13	15	7	13	14	ne	36
World	560	1019	264	200	373	267	141	130	57	362

[a] For coal, only a part of the ultimate resource (~ 15 percent) has been included because the figures are already very large for the time horizon of 2030 and because of the many uncertainties about very long-term coal resources and production technologies.

[b] Cost categories represent estimates of costs either at or below the stated volume of recoverable resources (in constant 1975$).

For oil and natural gas:	Cat. 1:	12$/boe
	Cat. 2:	12–20$/boe
	Cat. 3:	20–25$/boe
For coal:	Cat. 1:	25$/tce
	Cat. 2:	25–50$/tce
For uranium:	Cat. 1:	80$/kgU
	Cat. 2:	80–130$/kgU

Source: IIASA (1981).

Table 2-3. Implied theoretical upper limits for maximum extraction of primary energy sources and maximum production of secondary energy (GWyr/yr).

	1980		1990		2000	
Region I						
Coal	650	(679)	1100	(797)	1500	(935)
Oil	680	(715)	935	(863)	1235	(907)
Gas	–	(743)	–	(776)	–	(779)
Electricity and heat						
Hydro	55	(123)	63	(149)	73	(188)
Nuclear	42	(63)	99	(59)	220	(69)
Other	–	(434)	–	(427)	–	(489)
Total	–	(620)	–	(635)	–	(740)
Liquids						
light	–	(898)	–	(940)	–	(949)
fuel	–	(1142)	–	(1155)	–	(1095)
Coke	–	(44)	–	(41)	–	(38)
Region II						
Coal	875	(830)	1380	(1240)	1675	(1560)
Oil	710	(710)	770	(750)	820	(820)
Gas	465	(460)	770	(640)	1045	(780)
Electricity and heat						
Hydro	24	(27)	36	(41)	46	(53)
Nuclear	19	(27)	52	(75)	106	(142)
Other	–	(440)	–	(634)	–	(880)
Total	–	(494)		(750)	–	(1075)
Liquids	–	(626)	–	(698)	–	(767)
Coke	–	(0)	–	(0)	–	(0)
Region III						
Coal	550	(498)	650	(528)	800	(578)
Oil	485	(195)	490	(225)	405	(261)
Gas	310	(247)	330	(300)	350	(367)
Electricity and heat						
Hydro	74	(171)	75	(183)	75	(187)
Nuclear	33	(58)	90	(114)	219	(207)
Other	–	(413)	–	(485)	–	(638)
Total	–	(642)	–	(782)	–	(632)
Liquids						
light	–	(662)	–	(630)	–	(631)
fuel	–	(505)	–	(400)	–	(286)
Coke	–	(126)	–	(125)	–	(131)

Table 2-3. *Continued.*

	1980		1990		2000	
Region IV						
Coal	38	(75)	85	(38)	140	(85)
Oil	365	(388)	545	(413)	755	(524)
Gas	–	(70)	–	(109)	–	(183)
Electricity and heat						
Hydro	20	(50)	32	(96)	50	(149)
Nuclear	8	(0)	33	(5)	73	(15)
Other	–	(30)	–	(49)	–	(62)
Total	–	(80)	–	(150)	–	(226)
Liquids						
light	–	(226)	–	(284)	–	(415)
fuel	–	(200)	–	(146)	–	(136)
Coke	–	(8)	–	(13)	–	(19)
Region V						
Coal	170	(93)	320	(151)	450	(241)
Oil	350	(321)	445	(371)	495	(403)
Gas	–	(47)	–	(110)	–	(186)
Electricity and heat						
Hydro	16	(31)	24	(64)	45	(137)
Nuclear	7	(2)	25	(8)	56	(39)
Other	–	(46)	–	(89)	–	(103)
Total	–	(79)	–	(161)	–	(279)
Liquids						
light	–	(117)	–	(216)	–	(347)
fuel	–	(99)	–	(112)	–	(110)
Coke	–	(20)	–	(31)	–	(41)
Region VI						
Coal	–	(1)	–	(2)	–	(9)
Oil	1330	(1476)	1470	(1308)	1760	(1214)
Gas	-	(71)	–	(110)	–	(206)
Electricity and heat						
Hydro	2	(5)	2	(6)	2	(7)
Nuclear	7	(0)	25	(0)	55	(0)
Other	–	(16)	–	(40)	–	(80)
Total	–	(21)	–	(46)	–	(87)
Liquids						
light	–	(122)	–	(180)	–	(272)
fuel	–	(82)	–	(84)	–	(78)
Coke	–	(1)	–	(1)	–	(2)

Table 2-3. *Continued.*

	1980		1990		2000	
Region VII						
Coal	500	(470)	1206	(670)	2000	(917)
Oil	–	(143)	–	(210)	–	(322)
Gas	–	(20)	–	(51)	–	(170)
Electricity and heat						
Hydro	5	(9)	6	(3)	8	(20)
Nuclear	6	(0)	25	(2)	55	(5)
Other	–	(30)	–	(54)	–	(91)
Total	–	(39)	–	(69)	–	(116)
Liquids						
light	–	(110)	–	(177)	–	(316)

Annex 3.

CAPITAL REQUIREMENTS IN THE ENERGY SECTOR

This part of the report reviews current capital costs in the energy sector. Various sources of information have been used. Much of the data comes from IIASA internal sources based on engineering information and is presently being utilized within the IIASA system of energy models (Rogner 1984). But the results of other studies were also used, including IIASA (1981), IEA (1983), Bechtel National Inc. (1978), and MWV (1983).

In this section we will examine in turn the following energy industries: oil and gas extraction, coal extraction, utilities, and oil refineries.

Oil and Gas Extraction

Average capital costs associated with oil and gas extraction are hard to estimate reliably, first because costs vary significantly from country to country, and second because of the difficulties of factoring exploration costs into overall production costs – since exploration is usually costed on a well basis and not in terms of the amount of oil that might be extracted. One possible method might be to relate current expenditure on exploration to current production; on this basis, the IEA (1983) reports exploration costs of 3–5 US $ per barrel of oil produced.

Estimates of the investment requirements for oil and gas production (excluding exploration and transport costs) are presented in Tables 3-1 and 3-2 and show the wide variety of capital requirements, depending upon geographical location and extraction conditions. In general, very low costs are observed for major oil-producing areas (such as Saudi Arabia, Libya, and Algeria). Conversely, non-OPEC oil producers such as North America or the European North Sea countries have much higher costs.

Table 3-1. Average capital requirements for oil and gas production.

Category	Capital requirement (1983 US $)
Oil (per barrel per day)	
Conventional low cost	170-11420
Conventional medium cost	12000-14000
Conventional high cost	14400-119000
Enhanced oil recovery	24800
Heavy oil and tar sand	37200
Oil shales	37200
Gas (per thousand cubic feet per day)	
Low cost	1900
Medium cost	3000
High cost	6000

Source: IEA (1983).

Coal Extraction

Capital costs for coal production (Table 3-3) vary not only between the major producing regions but also within each region, depending on whether the developments concerned are surface or underground and whether or not new capacity is generated via increased production from existing mines. The comparatively low average capital requirements for western Europe reflect the fact that most new capacity in that region stems from existing mines.

Utilities

Utilities cover a wide range of different techniques used to produce electricity or steam. However, the distribution of gas and steam, which is normally included as part of utilities, will be excluded here. The capital cost of electricity generally depends heavily on the mode of generation. While the capital requirements (in 1980 US $) of a conventional boiler-fired power plant vary between 450 and 1150 US $ per kW capacity, depending mostly on whether or not flue gas desulphurization (FGD) is utilized; the corresponding figures are about 1500 $ per kW for light water reactors (LWR) and about 2500 $ per kW for hydro power plants. Table 3-4 presents details of investment costs by countries and by generation techniques.

Table 3-2. Capital requirements for oil and gas production by regions and areas.

Regions local conditions	Capital requirement (per barrel oil equivalent per day)
Regions	*1978 US $*
Africa	
Major oil producers	535–3310
Other	1846–5078
Australia	2673–298,549
South America	
Major oil producers	644–31719
Other	9212–23963
Europe	
North Sea	6088–8908
Other	2710–57,791
Far East	
Major oil producers	807–1785
Other	2817–90118
Middle East	106–7290
North America	1800–76,000
Local conditions	*1975 US $*
Giant fields (Saudi Arabia, Libya, Algeria)	
Oil	4000–5500
Gas	1600–3200
Relatively favorable conditions (USA, North Sea)	
Oil	7500–10000
Gas	6500–10000
Extreme conditions (deep offshore, polar regions)	
Oil	28000–38000
Gas	33000–40000

Sources: IEA (1983), IIASA (1981).

Refineries

A petroleum refinery incorporates a combination of processes and operations designed to convert crude oil, containing a mixture of more than a thousand different types of hydrocarbon, into a variety of usable products. In the first stage, the crude oil is separated into a number of fractions by distillation. The number of different fractions will be determined by the type of crude oil used. To adapt the product mix of the refinery to the market, some of the fractions for which there is

Table 3-3. Capital requirements for coal extraction.

Area	Capital requirement (1983 US $ per ton per year)
South Africa	49
Australia	69
Canada	116
Great Britain (new sites)	150-250
Average western Europe	33
Least developed countries	>100

Source: IEA (1984).

Table 3-4. Capital requirements for electricity generation.

Country	Capital requirement (1980 US $ per kW)
Boiler fired power plants	
Denmark (without FGD)	450-540
Japan (without FGD)	578
USA (without FGD)	725-975
USA (with FGD)	880-1150
FRG (with FGD)	789
Japan (without FGD)	902
Sweden (atmospheric fluidized bed boiler)	790-950
Nuclear power plants	
Denmark (LWR)	1390
FRG (LWR)	1657
Japan (LWR)	1442
Switzerland (LWR)	2071
USA (LWR)	1400
FRG (advanced converter reactors)	2010
Japan (advanced converter reactors)	960-1466
UK (advanced converter reactors)	2645
USA (advanced converter reactors)	1500
Hydro power plants	
Switzerland (runs of river)	2520
Switzerland (hydro-storage)	2710
Japan	2378
USA	1500

a low demand are converted into more saleable products. In later stages, therefore, the fractions are further transformed into products of lower molecular weight ("cracking") or higher molecular weight ("reforming") before additional purification and distillation steps. The capital costs of the refinery depend to a certain extent on whether simple, thermal refining and reforming processes or more advanced techniques, such as catalytic cracking, hydrocracking, or visbreaking, are used.

Table 3-5 shows the capital costs of different types of refinery. Due to a general shift to the use of heavier crude oils, as lighter crudes become exhausted, refining facilities need to become more and more sophisticated, and therefore the average capital requirement per unit of throughput will progressively increase.

Table 3-5. Capital requirements for refining.

Process	Capital requirement (1983 US $/ton/year)
Simple refining, including reforming	25
Complex refining, including catalytic cracking and visbreaking	92
Deep refining, including deasphalting and hydrocracking of residues	345

ANNEX 4.

International Energy Workshop

Summary of Poll Responses

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January 1985

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IEW Poll Respondents, January 1985

Includes only those responses dated 1983 or later.

Organization/project		Last Year Reported	Country/Region Coverage
AGABD, AGAHD, AGALD	American Gas Association - base, low, high demand, May 1984	2000	USA
ASSU	Academy of Sciences of the USSR, June 1983	2010	USSR
BLNCE	BALANCE Canadian Energy Model, T.E. Daniel and H.M. Goldberg, University of Alberta, January 1984	2000	Canada
BNL	Brookhaven National Laboratory, 1983	2010	USA
BP	British Petroleum, October 1984	2000	4,7, 5+6, OECD Europe, USA
CEC, CECCP, CECEU, CECFC	Commission of the European Communities - cooperation, Europe, and free competition scenarios, and results identical for all 3 scenarios, June 1983	2000	Belgium, Denmark, Federal Republic of Germany, France, Greece, Ireland, Italy, Luxembourg, Netherlands, United Kingdom
CERG	Cambridge Energy Research Group, 1985	2010	4,7
CHASE	Chase Manhattan Bank, March 1983	2000	7
CHVRN	Chevron Corporation, July 1984	2010	4
CIESH, CIESL	Center for International Energy Studies, Erasmus University - high and low energy growth, October 1984	2010	3-8
CON	Conoco, April 1984	2000	4-7, 5+6, Africa Asia, Japan, Latin America, Middle East, OECD Europe, Other OECD, USA

CPON	Central Planning Office, Netherlands, October 1984	2000	Netherlands
CRAN	A. Cranston, U.S. Senate, August 1983	2000	USA
CRIEH, CRIEL, CRIER	Central Research Institute of Electric Power Industry - high, low and reference GNP growth, November 1983	2010	Japan
CZMOE	Czechoslovakian Federal Ministry of Fuel and Energy, 1983	2000	Czechoslovakia
DNMOE	Danish Ministry of Energy, 1983	2000	Denmark
DOE	US Department of Energy, Office of Economic Analysis, January 1985	2010	4-7, USA
DRI	Data Resources Inc., November 1984	2000	4,5,8, USA
DRIE	DRI Europe, September 1984	2000	OECD Europe
EEF	UN Economic Commission for Europe, General Energy Unit, "An Efficient Energy Future," March 1983	2000	1, USA
EIA	US Energy Information Administration - 1990 midprice scenario, 1984	1990	4,7, 5+6, OECD Europe/North America/Pacific
ENI	Ente Nazionale Idrocarburi, 1983	1990	4
EPRIM, EPRIR	O. Yu, Electric Power Research Institute - minimum and reasonable expectations, December 1983	2000	USA
ERIEA	J.Edmonds and J. Reilly, Institute for Energy Analysis, July 1983	2000	1-4,7,8 Middle East, Other market economies
ESCN	Energy Study Centre, Netherlands, December 1984	2000	Netherlands
ETAMC	ETA-MACRO, J.-L. Aburto, A.S. Manne and S. Rogers, Trinational Project, January 1985	2010	Canada, Mexico USA

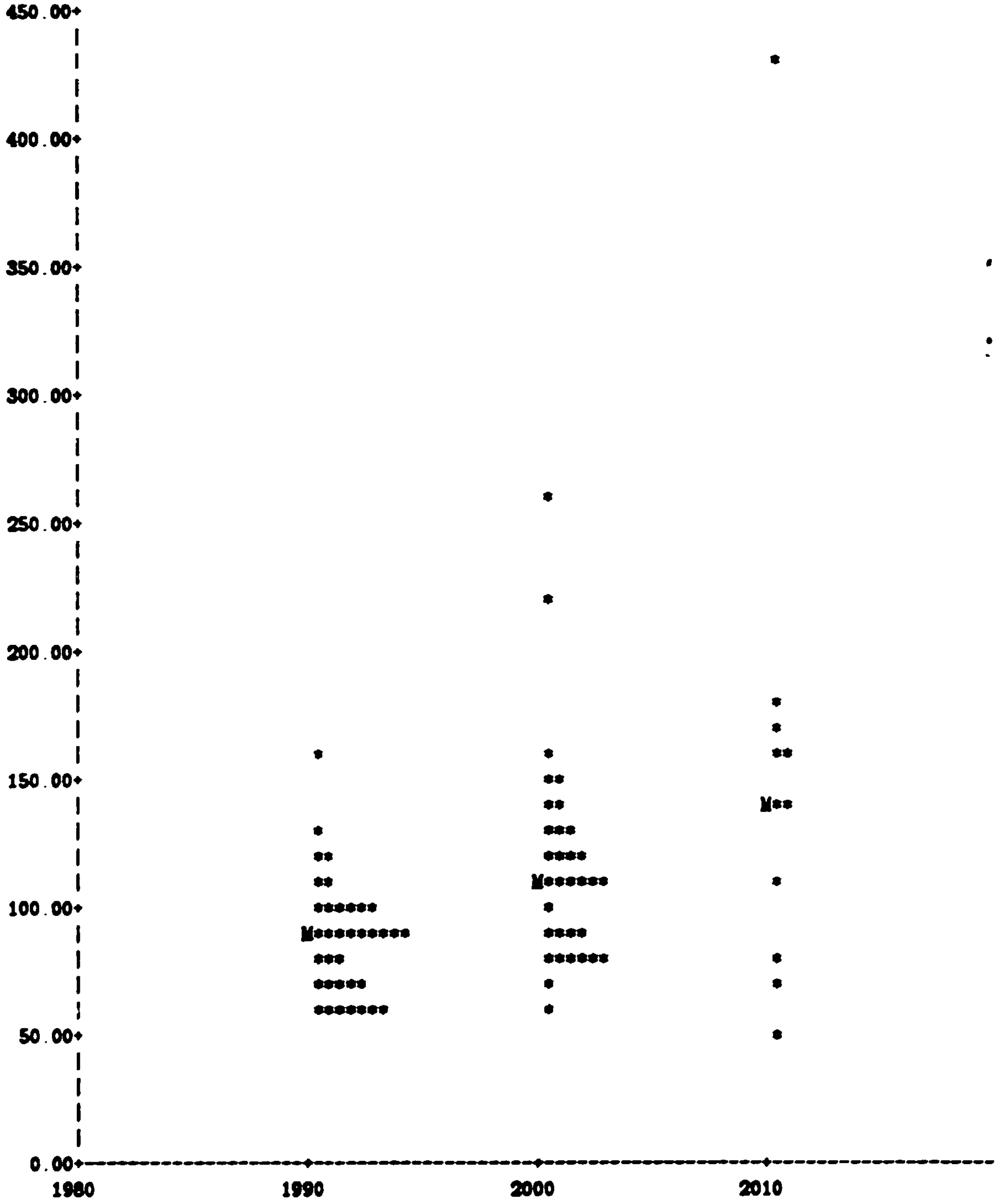
ETSHD, ETSLD	Energy Technology Systems Analysis Project of the International Energy Agency - high and low demand cases, 1983	2010	Australia, Austria, Belgium, Federal Republic of Germany, Ireland, Italy, Japan, Netherlands, Norway, Spain, Sweden, Switzerland, United Kingdom, United States; Sum of 14 IEA countries
GATLY	D. Gately, New York University, 1983	2000	5,7
GNVBD, GNVHD, GNVLD	University of Geneva - base, high and low demand, August 1983	2000	Switzerland
GRI	Gas Research Institute, October 1984	2000	USA
GULFC, GULFH, GULFP	Gulf Oil Corporation, Economics Division, slow climb, hard times and plateau scenarios, December 1983	2000	7, USA
HNPO	Hungarian National Planning Office, Energy Modeling Group, January 1984	2010	Hungary
IAEAH, IAEAL	International Atomic Energy Agency - high and low demand September 1984	2000	4, Eastern Europe, Latin America, OECD Europe/ North America/ Pacific
IEA	International Energy Agency, 1984	2000	4
IFPF, IFPM, IFPS	Institut Français du Pétrole - solid and moderate revival, stagnation, September 1983	2000	3-8
IIAGS	International Institute for Applied Systems Analysis - gas study, July 1984	2010	OECD Europe
IIASA	International Institute for Applied Systems Analysis, November 1983	2010	1-4,7-8

INBST	J. Brady, National Board for Science and Technology, Ireland, April/May 1983	2010	Ireland
IND	Standard Oil Company of Indiana, May 1984	2000	1-8, Other Market, Other CPE
IPE	IPE Model, N. Choucri, Massachusetts Institute of Technology, April 1984	2000	4-7
ISP	K.-P. Moeller, ISP Energy Projections, 1983	2000	Federal Republic of Germany
JAERI	Japan Atomic Energy Research Institute, March 1983	2010	Japan
LEOB	W.J. Schmidt, University of Mining and Metallurgy, Leoben, 1983	2010	8
MERZ	N. Merzagora, Economic Analysis Division, ENEA, June 1983	2000	Italy
NEB	National Energy Board, September 1984	2000	Canada
NGODP	International Natural Gas Study, Harvard University, and the OPEC Downstream Project, East-West Center, B. Mossavar-Rahmani and F. Fesharaki, 1983	1990	5; Algeria, Ecuador, Gabon, Indonesia, Iran, Iraq, Kuwait, Libya, Nigeria, Qatar, Saudi Arabia, United Arab Emirates, Venezuela
NRMPE	Norwegian Royal Ministry of Petroleum and Energy, 1984	2000	Norway
OBENA, OBENB	Observatoire de L'Energie - scenarios A and B, January 1983	2000	France
OLADE	Organización Latinoamericana de Energia, May 1983	2000	Latin America
OPEC, OPECD	Organization of Petroleum Exporting Countries - long-term energy models, domestic energy requirements, 1983	2010	4-7
PILOT	PILOT Model, P.H. McAllister and Model, Stanford University, March 1984	2000	USA
PIRNC	Petroleum Industry Research Foundation, Inc., September 1983	2000	3,7,8

REGBD, REGHD, REGLD	L. Lundquist, Research Group for Urban and Regional Planning - base, high and low demand, 1984	2010	Sweden
RESPH	Respondent H, 1983	2000	Japan
RESPI	Respondent I, 1983	2000	7; 5+6, Japan, OECD Europe, USA
RESPJ	Respondent J, March 1984	2000	Canada, Mexico, USA
RESPK, RESPL	Respondent K, L, December 1984	2000	4,5, USA
RESPM, RESPP	Respondent M, P, December 1984	2000	8
ROL	K. Roland, Central Bureau of Statistics, Norway, February 1984	2000	OECD Europe
ROWSE	J. Rowse, University of Calgary, November 1984	2000	Canada
SAUNS, SAUNV	H. Saunders, TOSCO, smooth and volatile scenarios, January 1984	2000	3-7
SHLLM, SHLLR	Shell International - muddling-through and restructuring, December 1984	2000	7, 8
SINGR	S.F. Singer, 1983	2010	4
SMIE1, SMIE2	Spanish Ministry of Industry and Energy - scenarios 1 and 2, 1983	2000	1,2,8, Africa, Japan, Latin America, Middle East, OECD Europe/ North America/ America, South Asia, Southeast Asia, and Australasia
SMIL	V. Smil, University of Manitoba, 1983	2010	2,8
SWEA	Swedish National Energy Administration, December 1984	1990	Sweden
TATA	R.K. Pachauri, Tata Energy Research Institute, 1983	2010	India

TAVNR	TAVANIR Corporation, Energy Ministry of Iran, April 1984	2010	Iran
TRT4, TRT6	3RT Model, A. S. Manne and P. V. Preckel, Stanford University - elasticities of OECD oil demand substitution = .40,.60, December 1983	2000	4-7
UN	United Nations Statistical Office, June 1984	1980	1-8
UNIDO	United Nations Industrial Development Organization, February 1983	1990	2, Eastern Europe, Japan, Latin America, OECD Europe/North America
WBK	World Bank, 1984	1990	1-8
WECHG, WECLG	World Energy Conference - high and low growth, December 1983	2000	1-3,7,8, 5+6, Africa South of Sahara, Latin America, North Africa and Middle East, OECD Europe/ North America/ Pacific, South Asia, South-East Asia
WILPP, WILRF	J. Willars, policy projection and reference case, November 1983	1990	Mexico

INTERNATIONAL PRICE OF CRUDE OIL, RESPONSES DATED 1984-85
1980 = 100



N.B. 1984 PRICE INDEX = 67 ($28/BARREL).

INTERNATIONAL PRICE OF CRUDE OIL, RESPONSES DATED 1984-85

	1980		1990		2000		2010
MEDIANS:	100.000		89.500		109.000		141.000
AGABD	100.000	REGLD	163.000	REGLD	265.000	REGLD	432.000
AGAHD	100.000	IPE	125.300	BLNCE	218.000	REGBD	181.000
AGALD	100.000	REGBD	122.000	PILOT	162.000	CHVRN	166.500
BLNCE	100.000	BLNCE	121.000	SAUNS	153.000	DOE	164.500
BP	100.000	ESCN	106.000	REGBD	149.000	ETAMC	164.500
CERG	100.000	WBK	106.000	RESPP	144.000	IIAGS	141.000
CHVRN	100.000	CPON	105.000	CPON	140.000	CERG	140.000
CIESH	100.000	ROL	105.000	AGALD	132.000	DRI	106.000
CIESL	100.000	AGABD	100.000	ESCN	130.000	REGHD	82.000
CPON	100.000	AGALD	100.000	IPE	129.200	CIESL	70.000
DOE	100.000	IIAGS	100.000	AGABD	122.000	CIESH	55.000
DRI	100.000	SWEA	98.000	IIAGS	122.000		
DRIE	100.000	SAUNS	94.000	CERG	120.000		
EIA	100.000	PILOT	92.200	ROL	120.000		
ESCN	100.000	RESPK	91.000	CHVRN	113.800		
ETAMC	100.000	EIA	90.000	HMPO	110.000		
HMPO	100.000	HMPO	90.000	DRIE	109.000		
IEA	100.000	REGHD	90.000	RESPJ	106.000		
IIAGS	100.000	AGAHD	89.000	DOE	105.500		
IPE	100.000	DRIE	89.000	ETAMC	105.500		
NEB	100.000	CIESL	87.500	RESPK	97.000		
NRMPE	100.000	RESPM	81.000	RESPM	95.000		
PILOT	100.000	CERG	80.000	DRI	92.000		
REGBD	100.000	RESPP	78.000	AGAHD	89.000		
REGHD	100.000	CHVRN	74.900	NEB	86.000		
REGLD	100.000	RESPJ	73.000	RESPL	83.000		
RESPJ	100.000	CIESH	72.500	BP	82.200		
RESPK	100.000	NEB	72.000	NRMPE	82.000		
RESPL	100.000	RESPL	70.000	REGHD	82.000		
RESPM	100.000	NRMPE	65.000	IEA	79.000		
RESPP	100.000	DOE	64.800	ROWSE	78.000		
ROL	100.000	ETAMC	64.800	CIESL	75.000		
ROWSE	100.000	DRI	64.000	CIESH	65.000		
SAUNS	100.000	ROWSE	64.000				
SWEA	100.000	BP	62.500				
WBK	100.000	IEA	58.800				

ANNEX 5.

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