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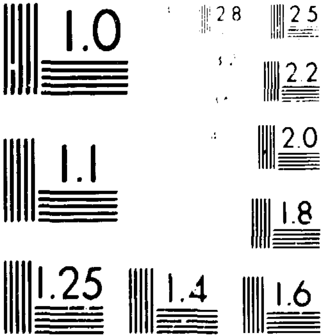

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ENERGY INTENSITY AND INDUSTRIAL DEVELOPMENT STRATEGY*

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ENERGY INTENSITY AND INDUSTRIAL DEVELOPMENT STRATEGY

This paper examines and appraises some of the trends in the energy field which bear relevance to the achievement of the Lima target.

Analysis of the primary energy requirements in both developed and developing countries show that the future imbalances of demand and supply are of such a magnitude that unless immediate and far-reaching policy actions were undertaken by both developed and developing countries, the achievement of the Lima target will not be possible.

Examination of the final energy demand by end-users vis-à-vis the development pattern reveals that the energy intensity of production tends to increase significantly in periods of social and economic transformation. This is particularly noticeable in the industrial sector in which processes and product-mix change drastically during rapid industrialization.

Detailed examination of energy use shows the importance of a few energy-intensive industries in the overall final energy consumption. This importance points to the need for further increase in the efficiency of energy use. The latter can be achieved through technological progress, specific conservation measures, and appropriate industrialization strategies regarding the industrial structure and the output-mix.

The Energy Dimensions of the Lima Target

The Lima target stipulates that by the year 2000 at least 25 per cent of the world manufacturing output should be produced by the developing countries. This implies that high rates of GDP growth with significant structural changes must be achieved by the developing countries. Assuming that the GDP of the developed countries (DDs), from 1975 to 2000, grows at an average rate of 3.7 per cent, the developing countries (DGs) should grow at a corresponding rate of 7.3 per cent in order to achieve the Lima target. The respective growth rates for manufacturing value added (MVA) should accordingly be 4.2 per cent for the DDs and 8.8 per cent for the DGs. Based upon this scenario, the order of magnitude of future demand for primary energy can be derived and compared with the energy supply conditions to be expected by the year 2000.

Given such a growth scenario, global demand for primary energy will increase from roughly 6,000 million tonnes of oil equivalent (MTOE) or 120 million barrels of oil equivalent per day (MBDOE) in 1975 1/ to 15,150 MTOE or 303 MBDOE by the year 2000. Of this total, the primary energy requirements of the industrialized countries (developed market and centrally planned economies together) will grow from 5,200 MTOE in 1975 to 10,850 MTOE or 217 MBDOE in 2000. The energy requirements of the developing countries which were 765 MTOE will grow to 4,300 MTOE or 86 MBDOE in 2000. 2/ In other words, the share of the developing countries in world primary energy requirements would then roughly double, from 13 per cent to 28 per cent.

The growth pattern up to 2000 differentiated for three country groups (developed market economies, developed centrally planned economies and the developing countries), and the corresponding elasticities of primary energy requirements for the three intermediate time periods used for projection are shown respectively in Tables 2 and 3. The starting values of the primary energy demand elasticities correspond to the experience of the recent past; the subsequent drop, however, can be attributed to improvements in energy efficiency and conservation efforts.

Assuming a continuous development effort of all energy resources throughout the world, the global supply capacity of primary energy is expected to reach 14,150 MTOE or 283 MBDOE by 2000 (Variant A). However, if the OPEC countries impose a production ceiling at the current level of crude oil production of 30 MBD (1,500 MT), the global supply by 2000 cannot be expected to exceed 13,400 MTOE or 268 MBDOE (Variant B). 3/

1/ As these figures include non-conventional energy, they are somewhat higher than some of the figures for primary energy requirements in 1975 which usually include only conventional primary energy (coal, petroleum, gas and hydro and nuclear electricity).

2/ In accordance with the growth scenario used Centrally Planned Asia was excluded.

3/ The estimates of potential supply of primary energy have been made on the basis of the World Energy Conference 1977 and the Workshop on Alternative Energy Strategies 1977.

Table 1 Primary Energy requirements in million tons of oil equivalent

	Developed Market Economies	Developed Centrally Planned Economies	Developing Countries	Total
1975	3600	1600	765	5965
2000	6700	4150	4300	15150

Table 2 Assumed GDP Growth rates in per cent p.a.

	Developed Countries	Developed Market Economies	Developed Centrally Planned Economies	Developing Countries
1975-80	3.4	3.0	5.0	6.2
1980-90	3.7	3.2	5.2	7.4
1990-2000	3.9	3.4	5.4	7.7

Table 3 Elasticities of primary energy consumption with respect to GDP

	Developed Market Economies	Developed Centrally Planned Economies	Developing Countries
1975-80	0.87	0.80	1.15
1980-90	0.82	0.75	1.05
1990-2000	0.70	0.70	0.85

A comparison of the projected primary energy requirements with the potential supply capacities reveals that in the scenario for achieving the Lima target by 2000, there is a primary energy deficit of 1000 MTOE or 20 MBDOE for variant A, and 1,750 MTOE or 35 MBDOE for variant B. To illustrate the order of magnitude for this gap, it should be recalled that in 1977 total OPEC crude oil production amounted to 30 million barrels per day. Even under an optimistic assumption, there will be 6.6 per cent of primary energy requirements unfulfilled by 2000. The corresponding figure under a more realistic assumption comes to 11.6 per cent.

This imbalance primarily stems from the global shortage of liquid fuels. Under optimistic assumption regarding future supply capacities, the balances for liquid fuels (crude oil and natural gas liquids) by country type would be as follows:

	Balance (in MBDOE)
Developed Market Economies	-49.5
Developed Centrally Planned Economies	-13.6
Developing Countries	+14.3
Total	-48.8

In the 1980s, the global oil balance can still be maintained with only developed market economies displaying a large liquid fuel deficit. After 1990, however, the situation takes a dramatic turn. Although DGs as a group still achieve a surplus, this surplus exists only in the OPEC countries while the other DGs can satisfy only part of their primary oil requirements. Thus not only will the growth potential of DDs be seriously impeded, but the same effect will be felt in the non-OPEC DGs.

While the potentials for expanding the supply by surveying the conventional energy sources and studying the prospects of new energy sources cannot be overestimated, it is equally important to study the demand side of the energy problems

1/ These figures are derived on the basis of a constant fuel mix for each country type. However, tentative calculations show that gradual changes in the fuel mix would not alleviate the situation. Drastic changes are necessary.

Accordingly, we will re-examine the global energy demand projection on the basis of detailed cross-country and time-series data.

Development Pattern and Final Energy Consumption

The present structure of the world energy economy is characterized by severe asymmetries; on a per capita basis, for instance, the developed market economies consume 15 times as much energy as DGs. Such a discrepancy reflects the equally severe asymmetries in the world-wide distribution of production and income on the one hand, and the higher energy intensity of GDP in DDs on the other.

In analyzing the relationship between the total final consumption of energy and GDP, a puzzling problem arises. While the development of this relationship over time reveals a correlation between energy use and the stage of development, this cannot readily be identified in a cross-country analysis. Taking the energy intensity of GDP (defined as total final energy consumption per unit of value added) as an indicator, DGs seem to consume comparable amounts of TOE per unit of value added (measured in millions of US dollars) as the developed market economies. The cause for this hardly plausible result lies in the fact that the GDP figures converted in official exchange rates do not reflect the actual purchasing power. To illustrate this distortion, the energy intensities of GDP at official and purchasing-power-parity exchange rates for selected countries are given in Table 4, which clearly establishes the close relationship between energy intensity and the stage of development.

Table 4 Energy Intensity of GDP in TOE per Million US$ in 1973

	Official Exchange Rate	Purchasing Power Parity
Columbia	963	384
India	849	277
Iran	820	414
Kenya	481	233
Korea	1414	572
USA	1033	1033
Japan	656	619
France	564	570
Germany, F. R.	591	679
Italy	763	663
UK	879	733

Developments of the energy intensities of GDP over time in DDs and DGs are given in tables A to C in the annex. It is interesting to note the clear distinction between the highly industrialized countries, and semi-industrialized and other DGs. 1/ The turning point for the development of the highly industrialized countries seems to have been around 1970. Up to that point, the energy intensity continued to increase in the highly industrialized countries, while falling afterwards. To a certain extent this drop can be attributed to limited availability and rising cost of energy. However, the fact that in the sixties, energy intensity in the more mature economies of France and the United States had increased little, and it actually decreased in the United Kingdom, indicates that after a certain stage of development, structural changes alone would have brought about a decline in energy intensity. This, and the large inter-country differences between DDs lead to the conclusion that the potentials for increasing the overall energy efficiency of GDP in DDs are considerable.

Examination of the energy intensity of the semi-industrialized countries and DGs shows quite different trends with respect to GDP. In almost all cases, the energy intensity increased over time (from 1960 or 1967 to 1975). 2/ For the semi-industrialized countries, this development was especially marked since 1970, but the increases were still significantly smaller than for other DGs. This is remarkable since the energy-intensive manufactures like the iron and steel industry did expand quite rapidly in a number of these semi-industrialized countries. Among other DGs, the OPEC countries increased energy intensity by at least 2 per cent per annum. However, it was obviously not only the supply conditions which determined this behaviour, as some of other non-OPEC DGs also show large increases.

Industrial Energy Demand

a) Energy Shares for the Industrial Sector

The manufacturing sector, especially a few energy-intensive manufactures

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1/ Greece, Portugal and Spain are listed among other OECD countries in the tables. OECD classifies them together with Brazil, Mexico, Yugoslavia, Hong Kong, Korea, Taiwan and Singapore as newly industrializing countries. Here the term semi-industrialized countries is preferred.

2/ For the non-OECD countries the available data started only in 1967.

such as primary metals industries, chemical and petrochemical industry, fabrication of stone, glass and clay products, paper and allied products and food and kindred products, is a major final consumer of energy in every economy. Unfortunately available statistics do not permit a comparative analysis of the manufacturing sector alone, as the mining and construction sector are usually included. Nonetheless it is known that the major portion of energy consumption accrues to the manufacturing sector.

Tables D and E in the annex present, respectively, the shares of industry in total final consumption of energy, and the value added shares in 1975. In the highly industrialized countries in Europe, the industrial sector accounts for approximately 40 per cent of total final consumption of energy. The corresponding proportions are less than one third for the United States and more than one half for Japan. In the semi-industrialized and other DGs the variance is even higher with the industrial energy shares ranging from roughly one-fifth (Kenya) to over a half (India) of total final consumption in 1975. Thus no clear relationship between industrial energy and industrial value added share is discernible from the cross-country data.

The dichotomy between the highly industrialized countries on the one hand and the semi-industrialized and other DGs on the other can again be observed when the changes from 1960 or 1967 to 1975 are examined. Irrespective of changes in the relative position of industry in GDP, the share of industry in energy consumption generally decreases for highly industrialized countries and increases for the remaining countries.

It will be conjectured that up to a certain stage of development, the share of industrial energy consumption will increase. This assumption finds support in the trends of the energy intensity of industry, which tends to decline in the industrializing countries and rise in the semi-industrialized and other DGs. (See Tables F and G in the Annex).

In comparing the trends of the industrial energy intensity between countries (with the energy intensity of the US industry as reference), one can see that among highly industrialized countries, the relationships remain rather stable, whereas in the semi-industrialized countries a marked increase of the relative energy intensity of industry is observed (see Table H).

In view of the fact that the manufacturing sector accounts for a major portion of industrial energy demand, the implications of the above-mentioned trends are indeed important. Industrialization tends to increase the energy demand more than proportionately. A number of mechanisms are involved in this process (e.g. increase in the share of energy-intensive basic industries, substitution of commercial for non-commercial fuels, increased mechanization and substitution of energy for labour). The substitution of commercial energy for non-commercial energy forms, which are not included in this study, will certainly raise the energy-intensity of all forms of production. It should be noted that in most of DGs, for which data are available, the use of non-commercial energy in industry also increased.

An additional influencing factor is the increased mechanization of production processes. From the industry data, it is noted that in most manufactures, especially in the energy-intensive industries, more than 80 per cent of the energy is consumed in heat applications, to a great extent as process heat, and less than 20 per cent in mechanical applications. These relationships tend to be rather stable. Therefore, one should be cautious when assessing the influence of increased mechanization upon energy intensity of industry. 1/ It can thus be concluded that changes in the sectoral composition of output, and development in energy intensity of major energy-consuming industries constitute the main determinants for the future energy intensity of industry.

b) The energy-intensive industries

Among the energy-intensive industries which are at the same time the major energy consumers, data availability limits our analysis to only two, viz., the iron and steel industry and the chemical and petrochemical industry. Fortunately these two industries are the largest consumers of energy in manufacturing. In 1972, they accounted for nearly 60 per cent of energy consumed in manufacturing in the Federal Republic, and about one half in the USA. 1/ The shares of these two industries in total industrial (i.e. manufacturing has mining and construction) consumption for selected countries are presented in Table 5.

1/ The USA show also a high share of energy consumption by the mining sector. The shares of these two industries in the entire industrial sector are therefore much smaller.

Table 5

Share of Iron and Steel and Chemicals and Petro-Chemicals in Total Industrial Consumption of Energy, 1975 (per cent)

OECD - Highly Industrialized	
U.S.A.	34.2
Japan	66.4
France	50.0
Germany	57.4
Italy	53.5
U.K.	45.3
OECD - Other Countries	
Greece	57.5
Portugal	17.1
Spain	46.9
Turkey	40.0
DGs	
Brazil	37.1
India	42.3
Korea	62.4
Mexico	19.6 [a]
Thailand	6.5

[a] Iron and Steel only

In DDs, the influence of the iron and steel industry is relatively greater because of its larger share. In DGs the influence of the chemical and petrochemical industry is relatively smaller because of its relatively lower energy intensity (cf. table I in the Annex). The relative energy intensities of these two industries can also be seen from the comparison of their energy intensities with the industrial average given in Table 6.

Table 6 Relative energy intensities in 1975

	Industrial Sector as a whole	Iron and Steel	Chemical and Petrochemical
DDs	100	467	191
DGs	100	496	130

For the large steel producing countries, the energy intensity of iron and steel tends to decline. It fell at an annual rate of 2.6 per cent for the Federal Republic of Germany, 2.5 per cent for the United Kingdom, and 1.0 per cent for the United States from 1950s to early 1970s.

Countries with a newly established or rapidly expanding iron and steel industry show quite a different behaviour. The energy intensity of the iron and steel industry actually increases. This corroborates the observations in 1975 that the energy intensity of the iron and steel industry is higher in DGs than in DDs (see table J in the Annex). This difference can be attributed to the type of iron ore used, the extent of imported pig iron used, the difference in technology and the difference in final output-mix. Assuming that the iron and steel industry in DGs is to expand along the line of basic products, this inequality in energy intensity will tend to persist. It will only disappear when the industry becomes highly diversified.

Technological developments in the chemical and petrochemical industry generally have a lowering effect on the energy-intensity of this industry, both in the use of energy as feedstock and for energy applications. This declining tendency is partially offset by a rising share of petrochemicals and in some cases by changes in the output mix of specific branches. Such variations in the composition constitute a major cause for inter-country differences. In the past, the energy intensity of this industry appears to have decreased at a slower pace than for all manufactures. The rates of decline of the energy intensity amounts to 1.1 per cent in the United States and 0.4 per cent in the Federal Republic of Germany, as against 1.6 and 1.9 per cent for all manufactures. Due to the expected resource-based development of the chemical and petrochemical industry in DGs, the energy efficiency will probably have a slow increase. In contrast, higher efficiency gains can be expected for DDs in view of the conservation potentials of existing plants and higher efficiency of the new plants.

Concluding Remarks

The major result of the foregoing analysis is that even under rather optimistic energy supply assumptions and relatively modest expectations concerning future growth in DDs, the achievement of the Lima target will be impeded by the prospective energy deficit. In particular, for both the developed market economies with their heavy dependence on external supplies, as well as DGs with a similar portion of total energy requirements fulfilled by imported liquid fuels, the dominant position of liquid fuels must be reduced sharply. While the possibility of shaping the future fuel mix in an appropriate direction remains, this should be integrated into development programmes. Such a practice will avoid conversions of fixed capital assets in the future. Attention should also be directed to the fact that considering the real needs of end-users, the energy supplied and actually consumed is of too high a quality. This state of affairs implies a tremendous waste of energy resources and hinders the successful development and application of new energy sources.

Further consequences pertain to the type of the industrialization by which the Lima target could be attained. Since the conventional type of industrialization involving the establishment of energy-intensive industries will tend to aggravate their future energy balances, the logical consequences would be that countries with poor energy resources must undertake special efforts to facilitate their accelerated industrialization by designing an industrial structure in which the energy-intensive basic industries would play a lesser role, and where the focus would be placed on the improvement in the efficiency of industrial energy use.

A N N E X

TABLE A Indexes of energy intensity of GDP for OECD countries 1960, 1970 and 1975

	1960	1970	1975
OECD Highly Industrialized			
USA	100	103	91
Japan	100	124	102
France	100	106	97
Germany	100	110	103
Italy	100	146	141
U.K.	100	91	79
Total	100	125	110
OECD - Other countries			
Greece	100	146	159
Portugal	100	112	133
Spain	100	116	121
Turkey	100	141	225
Total	100	123	145

TABLE B Annual change of energy intensity of GDP for OECD countries since 1960 (per cent)

	1960/1970	1970/1975
OECD Highly Industrialized		
USA	0.03	- 2.4
Japan	2.2	- 3.8
France	0.6	- 1.8
Germany	1.0	- 1.3
Italy	3.9	- 0.7
U.K.	- 0.9	- 2.8
Total	2.2	- 2.5
OECD - Other Countries		
Greece	3.9	1.8
Portugal	1.1	3.5
Spain	1.5	0.8
Turkey	3.5	9.8
Total	2.1	3.3

TABLE C Indexes of energy intensity of GDP for Developing Countries 1967, 1970 and 1975

	1967	1970	1975	Annual change in percent from 1967 to 1975
Algeria	100	111	149	5.1
Argentina	100	106	100	-
Brazil	100	99	103	0.4
Colombia	100	88	80	- 2.8
Egypt	100	110	152	5.4
India	100	97	104	0.5
Indonesia	100	127	143	4.6
Iran	100	121	118	2.1
Jamaica	100	89	137	4.0
Kenia	100	77	103	0.4
Korea	100	110	103	0.4
Mexico	100	97	103	0.4
Nigeria	100	88	196	8.8
Saudi Arabia	100	121	121	2.4
Thailand	100	131	153	5.5
Venezuela	100	100	115	1.8
Total	100		105	0.7

TABLE D — Share of industry in total final consumption of energy and in GDP for OECD-countries, 1960 and 1975 (per cent)

		Energy share	Value added share
OECD Highly Industrialized			
USA	1960	33.6	36.1
USA	1975	29.2	33.6
Japan	1960	59.7	32.7
Japan	1975	53.0	41.0
France	1960	45.9	38.3
France	1975	37.5	41.3
Germany	1960	46.0	49.3
Germany	1975	39.2	49.2
Italy	1960	47.8	41.0
Italy	1975	45.4	42.8
United Kingdom	1960	39.4	52.3
United Kingdom	1975	38.4	41.0

TABLE D continued:

		Energy share	Value added share
OECD - Other Countries			
Greece	1960	30.8	25.5
Greece	1975	40.3	30.2
Portugal	1960	32.9	34.1
Portugal	1975	38.0	42.8
Spain	1960	44.1	31.8
Spain	1975	48.4	40.0
Turkey	1960	26.6	19.7
Turkey	1975	19.0	27.9

TABLE E Share of industry in total final consumption of energy and in GDP for selected developing countries, 1970 and 1975 (per cent)

	Energy share	Value added share
Brazil 1970	32.1	36.3
Brazil 1975	38.8	39.4
India 1970	51.5	24.0
India 1975	56.0	21.3
Kenia 1970	19.6	19.3
Kenia 1975	18.5	21.1
Mexico 1970	44.8	33.3
Mexico 1975	50.4	34.8
Thailand 1970	29.0	24.4
Thailand 1975	29.8	25.3
Venezuela 1970	45.7	65.3
Venezuela 1975	44.4	53.3

TABLE F   Indexes of energy intensity in industries for OECD countries, 1960, 1970 and 1974.

	1960	1970	1974	Annual rate of change 1960/70 (per cent)	Annual rate of change 1970/74 (per cent)
OECD Highly Industrialized					
USA	100	100	96	0	- 1.0
Japan	100	81	73	- 2.1	- 2.6
France	100	89	74	- 1.2	- 4.5
Germany	100	84	91	- 1.7	2.0
Italy	100	119	125	1.8	1.2
United Kingdom	100	101	99	0	- 0.5
OECD - Other Countries					
Greece	100	146	155	3.9	1.5
Portugal	100	86	109	- 1.5	6.1
Spain	100	102	115	0.2	3.0
Turkey	100	98	90	- 0.2	- 2.1

TABLE G Indexes of energy intensity of industries for Developing Countries, 1970 and 1975

	1970	1975	Annual rate of change (per cent)
Algeria	100	120	3.8
Argentina	100	99	- 0.2
Brazil	100	123	4.2
Egypt	100	129	5.2
India	100	121	3.8
Jamaica	100	100	0
Kenia	100	120	3.7
Korea	100	156	9.3
Mexico	100	115	2.8
Nigeria	100	190	13.6
Thailand	100	121	3.8
Venezuela	100	101	0.3

TABLE H Indexcs of relative energy intensity of industry for OECD countries, 1970 and 1975 (USA = 100)

	1970	1975
OECD Highly Industrialized		
USA	100	100
Japan	84	77
France	49	46
Germany	40	47
Italy	68	78
United Kingdom	74	80
OECD - Other Countries		
Greece	52	72
Portugal	32	48
Spain	58	69
Turkey	43	58

TABLE I Share of major energy-intensive industries in total final consumption for developed and developing countries, (per cent) 1975

	Iron and Steel Industry	Chemical and Petrochemical Industry	Together
Developing Countries			
Algeria	3.5	11.2	14.7
Brazil	5.1	9.3	14.4
Colombia	2.4	n.a.	n.a.
Egypt	6.0	n.a.	n.a.
India	16.8	6.7	23.5
Indonesia	n.a.	2.4	n.a.
Korea	3.3	8.5	11.8
Mexico	9.9	n.a.	n.a.
Thailand	0.3	4.3	4.6
OECD Highly Industrialized			
France	9.3	9.3	18.6
Germany	12.2	11.3	22.5
Italy	8.4	15.9	24.3
Japan	18.9	16.3	35.2
United Kingdom	7.6	9.8	17.4
United States	5.2	4.8	10.0
OECD-Other Countries			
Greece	11.8	5.9	17.7
Portugal	3.3	3.2	6.5
Spain	11.9	10.8	22.7
Turkey	3.6	4.0	7.6

TABLE J Indexes of energy intensities of the iron and steel industry in selected contries, 1975 (USA = 100)

OECD	
USA	100
Japan	102
France	56
Germany	58
Italy	92
United Kingdom	87
Developing Countries	
Algeria	125
Colombia	109
Egypt	123
Korea	135
Mexico	154