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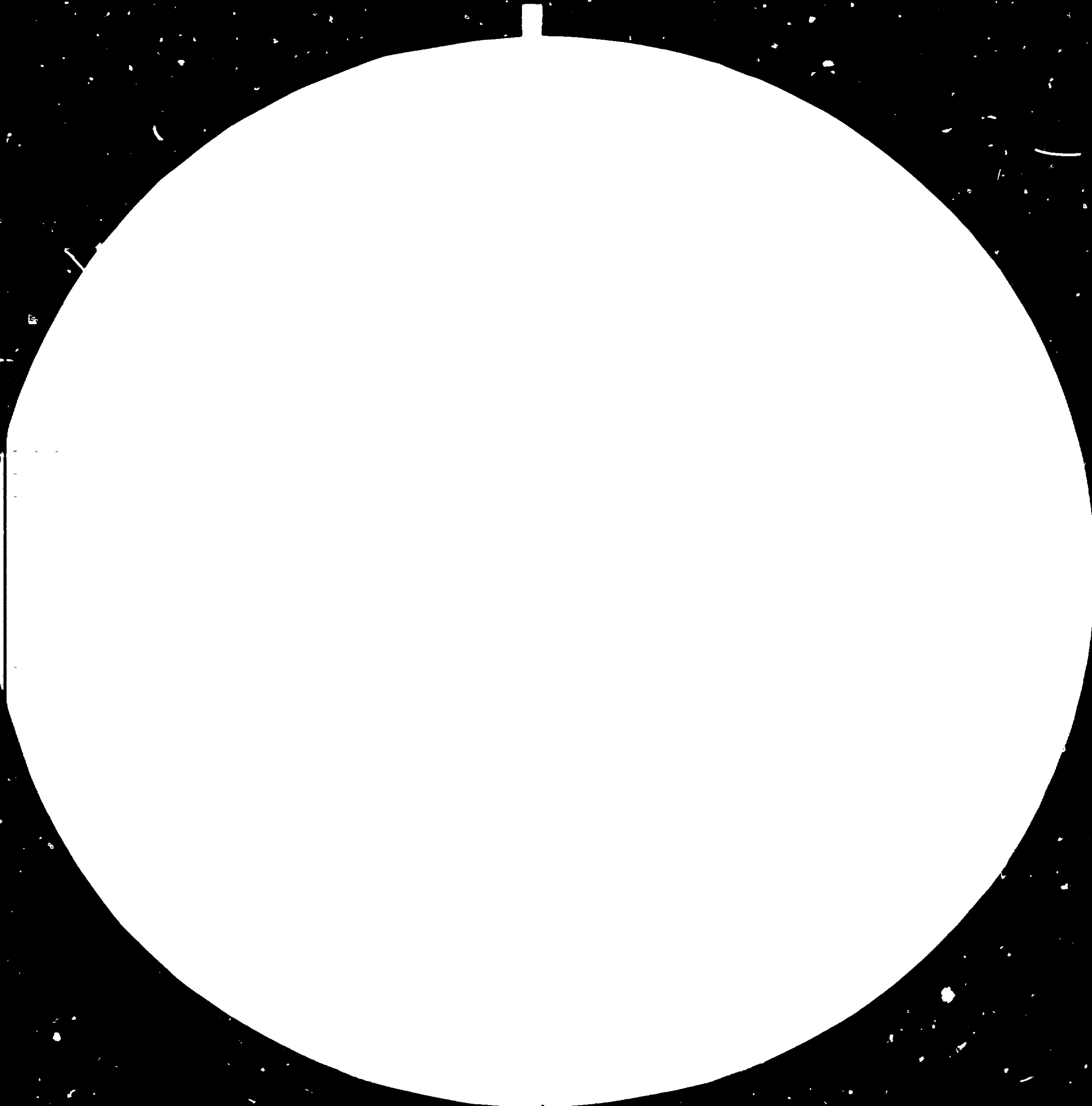

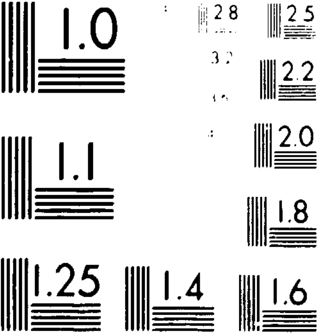
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ENERGY AND INDUSTRY

(With Special Reference to the Arab Countries)

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PART ONE: THE UNIDO FRAMEWORK, CONCEPTS AND METHODOLOGY

"When, in 1975, the Second UNIDO General Conference on industrialization established the Lima target, which stipulated that by the year 2000 the developing countries should produce at least 25% of the total world industrial output, it was clear that one essential prerequisite for achieving such a target would be the availability of energy. In early 1980 the Third General Conference of UNIDO in New Delhi devoted special attention to the energy problem and made explicit recommendations in this regard." 1/

"...industry is both a consumer of energy and a producer of items which require energy for their utilization. It also produces the necessary equipment for the production of energy, exhaustible or renewable, conventional or not. The energy demand for the operation of the industrial sector as such represents a sizeable share of the total energy demand, i.e. about 35%. However, the energy needed for use of the capital and consumer goods delivered by industry to the other sectors of the economy amounts to another 50% of total energy consumption. In other words, industrial activity is directly or indirectly responsible for the use of some 85% of the total energy consumed in the world. Therefore, and this is a crucial point, energy consumption and also energy efficiency are mainly governed by the creativity and productivity of the industrial sector through the continuous technological development of energy-efficient processes and products. Accordingly, I strongly believe that the interface energy/industry should be at the centre of your present deliberations since energy is a necessary input for the manufacture and use of industrial products and since industry, as I already mentioned, provides the equipment and processes for the energy sector itself." 2/

"New and renewable sources of energy are called for to play a significant role in the transitory period to the post-oil era. They are equally important for both the developed and the developing countries, but since the latter group is starting from a very low level of energy consumption, we may assume that, for the developing countries, energy from new and renewable sources can provide a more immediate opportunity and could indeed bring about some relief in terms of dependence vis-a-vis oil. In order to

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1/ Statement by Dr. Abd-El Rahman Khane, Executive Director of UNIDO at United Nations Conference on New and Renewable Sources of Energy (UNCNRSE), Nairobi, Kenya, 10-21 August 1981, para. 4.

2/ Ibid., para.5.

appreciate fully the role of these sources of energy in the developing countries, it is necessary to devote some attention to the quantitative aspects of their energy supply and demand situation for the period 1980-2000. The developing countries will have in 1980 an estimated joint GNP of the order of $ 2200 billion and their total energy consumption will be about 1700 megatons of oil equivalent, or 34 million barrels/day of oil equivalent. This includes non-commercial energy. For the year 2000, a projection consistent with the Lima target and the United Nations Third Development Decade would indicate a joint GNP of $9,000 billion (at the 1980 dollar value) with a total energy consumption of the order of 6500 megatons of oil equivalent, or 130 million barrels/day of oil equivalent. In other words, by the end of the century the <u>additional</u> energy input required would be of the order of 4800 megatons of oil equivalent, or 96 million barrels/day of oil equivalent. It will not only be most desirable but imperative that at least half of this amount should come from new and renewable sources of energy.

The above figures, rough estimates as they are and optimistic as they may be, are still of interest for purposes of broad long-term analysis. The real figures cannot turn out to be lower than two-thirds of the suggested values and thus the order of magnitude of the task is staggering, particularly if one bears in mind that by the year 2000 the oil reserves will be, as generally assumed, nearing exhaustion. In order to fill the gap, which is foreseen, it is obviously essential to start immediately, ... to mobilise all types of energy. As far as energy for industry is concerned, we consider <u>five</u> main sources: oil and gas, coal, nuclear power, hydro-power and biomass. Other sources such as wind, geothermal, etc. will be highly location- and purpose-specific. In all cases the lead time to develop new and renewable energy resources, when available, is quite considerable, even when these are conventional renewable sources, such as hydro-power and biomass." [1]

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[1] Statement by Dr. Abd-El Rahman Khane, Executive Director of UNIDO at the UN Conference on New and Renewable Sources of Energy (UNCNFSE), Nairobi, Kenya, 10-21 August 1981, paras. 6 and 7.

The Lima Declaration established what is known as the "Lima Target", namely that the developing countries' share in total world industrial production, ".... should be increased to the maximum possible extent and as far as possible to at least 25% of total world industrial production by the year 2000."[1]

This target already contains implicitly an energy target. The close inter-relationship between patterns of industrial development and energy supply was fully recognized at the Third General Conference (of UNIDO)*, at which it was stated that the "attainment of the Lima target through the accelerated establishment of industry would require adequate availability of energy resources." [2]

To review and analyze the present situation and the potential for development and application of energy sources in industry, it is necessary to examine: [3]

1. the impact of such utilization on the patterns of industrial production in the Arab countries;
2. the requirements for equipment and services that the development of the energy sector itself is likely to impose on the industrial sector of Arab countries,
3. the human, technological and financial requirements relating to the means and facilities for rational utilization of appropriate energy sources in industry.

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[1] UNIDO Draft Background Paper for the United Nations Conference on New and Renewable Sources of Energy (UNCNRSE), document presented at the Expert Group Meeting on Industrial Issues and Utilization in Transportation and other Allied Sectors, Vienna, 12-16 January 1981, (Document UNIDO/OED. 131, 3 March 1981), p. 1.

[2] UNIDO Document ID/CONF/4/22, p. 79, para. 103, cited in "Report on Energy-Related Industrial Development Activities, with special attention to the development and to the utilization of new and renewable sources of energy in industry," a document presented at the United Nations Conference on New and Renewable Sources of Energy, Vienna, 11 February 1981 (Document UNIDO/OED. 130, p.19).

[3] This approach is borrowed from a mere general formulation by UNIDO. See: "Expert Group Meeting on Industrial Issues and Utilization in Transportation and other Allied Sectors," UNIDO Document, OED.131 Draft Background Paper, 3 March 1981, p. 2.

(*) New Delhi, January 21- February 9, 1980.

1. Energy for Industry

"When considering their energy-related problems and opportunities, there is basically only one fundamental and broad issue facing Developing Countries in their industrialization efforts towards the target and objectives set in Lima and New Delhi, namely to develop and/or ensure the supply of energy required to establish and operate the industries, and related transportation and other allied systems, needed for their accelerated economic and social development and viable in terms of local conditions, resources and capabilities."

"UNIDO emphasizes the correlation between the pattern of available energy and the corresponding pattern of industries that can be established. The full development and utilisation of new and renewable sources of energy will require an unprecedented technological, industrial, planning and financial effort. Indeed, it is important to identify energy efficient industrial processes and products which best lend themselves to development on the basis of such new and renewable sources of energy, and that can lead to oil substitution." 2/

2. Industry for Energy

Industry is dependent on energy for "the development of the capital goods industry and of the industrial engineering services necessary for the development of energy sources in general and of new and renewable sources of energy, in particular. This implies the development of a full scientific technological and industrial capacity in the developing countries to handle research, design and engineering to develop or to service the large spectrum of capital goods needed by the energy sector. It is estimated that the total investment in the energy sector of developing countries, in the period 1980-2000 may reach 5-6000 billion dollars and that, of this amount, the equipment for harnessing and application of new and renewable sources of energy alone, will be worth no less than $1200 billion (1980 rate). Here again, even if lower estimates are considered,

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1/ UNIDO Draft Background Paper for the United Nations Conference on New and Renewable Sources of Energy (UNCNRSE), document presented at the Expert Group Meeting on Industrial Issues and Utilization in Transportation and other Allied Sectors, Vienna, 12-16 January 1981 (Doc.UNIDO/OED.131, 3 March 1981),p.1.

2/ Statement by Dr. Abd-El Rahman Khane, Executive Director of UNIDO at the UN Conference on New and Renewable Sources of Energy (UNCNRSE), Nairobi, Kenya, 10-21 August 1981, para. 11.

the corresponding effort in terms of technology, trained manpower and finance will have unprecedented dimensions. Yet it is worth pointing out that this equipment for new and renewable sources of energy would represent only 1.5% of the total accumulated GNP of developing countries between 1980 and 2000, which means that although the task is enormous it is not out of reach." [1]

3. Energy Management

"Energy management has to do with optimum development and use of the energy, both at the macro and micro levels. This problem has become very acute in recent years and rightly so. It deals with both national (and even regional) energy planning and with the optimisation of plant energy balances, with special attention on energy conservation. It also includes the optimisation of energy planning and use in urban and rural areas, with special attention to requirements for transportation needs." [2]

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[1] Statement by Dr. Abd-El Rahman Khane, op. cit., para. 13.

[2] Ibid , para. 14.

2. HOW TO TACKLE THE ENERGY-INDUSTRY RELATIONSHIP

(Concepts and Methodology)

From a conceptual view, one may question the relevance of the distinction commonly made (*) between commercial and non-commercial energy independently from their respective economic and social objectives and uses. Furthermore, when considering the potential for many renewable or non-conventional sources, this distinction may not be sufficiently operational. First, it does not accurately show the respective shares in the consumption pattern of the productive and the non-productive uses; of the subsistence and the export sectors, and of the industrial (including manufacturing) and other activities.

To characterize the present energy situation and to foresee its future development in the Arab countries, one would rather suggest the following conceptual framework:

1. On the side of energy production:
    a. assessment would be made of the degree of upgrading of indigenous energy sources by distinguishing advanced economic exploitation and/or primitive insufficiently upgraded production in the countries where one or both of the two patterns of upgrading are identifiable;
    b. the degree of upgrading of specific domestic sources with low energy efficiency by contrasting with the import of foreign energy with higher use of efficiency.
2. On the energy consumption side:
    a. distinction is to be made between energy utilized to sustain productive activity, directly in industry and agriculture, indirectly in the various forms of social consumption which are indispensable to carry out and to expand the economic development process; while satisfying broad social needs.
    b. a distinction is also to be made on the basis of sectoral sharing and degree of optimal use of energy in production and/or for subsistence. In the case of energy use, a further distinction could be made between the part of energy use in the primary production especially when intended to export markets and that use in manufacturing would either be home-oriented or destinated to exports.

(*) Notably by World Bank, World Energy Conference.

To sum up the definition of energy problem and of the energy to industry relationship in the Arab countries, it is necessary to assess the energy present situation and prospects in the following terms:

- energy consumption versus energy production
- energy necessary for economic and social use versus energy wastage
- optimal energy use in production versus inadequate energy use in production.

Following this line of thinking, one may legitimately question the approach to energy, reduced to a problem of trade balance, as formulated and applied by the World Bank, shadowing the essence of energy problem in the developing countries as one of the dependance on foreign economies either through over export of oil or through overgrowing imports of foreign oil, inseparatedly from primitive, if not absent, upgrading of indigenous alternatives to oil and intimately in connection with socially selective and narrow consumption and even over consumption for non-economic sake of imported or domestic petroleum.

The Energy-Manufacturing Industry Relationship

Another problem which needs to be clarified is the relationship of energy consumption and growth in manufacturing. In the developed countries, two-thirds of the industry produced is consumed by the industrial sector. Adding the transportation sector to industry the share attains 85% of the total energy consumption. Three main reasons could explain this: (1) industries are generally concentrated in these developed countries; (2) energy-intensive industries are also concentrated in these countries; (3) historically, oil-producing countries had been entitled to an insignificant rent for their oil; this has resulted in a world-wide productive pattern strongly dominated by industries and transportation sectors which are intensively consumer of oil.

In the developed countries, the rates of growth and the levels of energy consumption are determined less by the respective levels and shares of primary and manufacturing activities than by the respective shares of productive activities (whether primary or manufacturing), highly or moderately energy-intensive and non-productive energy-consuming sector in total energy consumption.

In most of the developing countries where industry is still hardly existent, energy-intensive industries have been only very limitedly expanded, but an imported gasoline-based transportation system was developed in urban centres to the advantage of urban minorities. It follows that the relationship of energy to industry and to industry and transportation, differs in these developing countries from that of the developed countries as described above.

In order to characterize the present situation and prospects of energy and industry relationship in the Arab countries, we suggest the following methodology:

1. to characterize the resource structure and fracture particularities as well as the economic and social policies of the countries.

2. to characterize the magnitude of non-productive in total consumption and to compare it to energy domestic production and eventual oil imports.

3. to examine and characterize the producting structure from the point of view of energy consumption, and to measure its energy intensity and efficiency.

Such a method seems appropriate not only for Arab countries but also for the other developing nations faced with energetic, industrial and development challenges. It follows that the presence of an important energy consuming, but non-productive sector leads to serious dependence on foreign energy supplies even in the absence of a significant manufacturing or other industrial activities. (As in the case for Costa Rica).

Along the same line of thinking, one can say that the presence of a significant producing sector, primary or manufacturing, but intensively consumer of imported energy results in a state of energy dependency which is more accurate than that of other developing countries with a producing sector, primary or even manufacturing, but less energy intensive. This applies to many developing countries with agricultural and manufacturing industries that are not large consumers of energy.

A scenario was simulated and developed to suggest a strategy of collective self-sufficiency for all Arab countries.[1] The conclusions reached in this scenario showed that:

1. the Arab World would achieve a high rate of growth in the GDP as an absolute result of the collective factor (joint action)
2. added value in manufacturing industry would increase both in size and significance, as well as per capita.

With respect to the Arab World as a whole, production of consumer goods would represent according to this scenario, approximately 46.7% of the total added value in manufacturing industry; intermediate goods representing 27% (a general trend towards concentration on this category, particularly oil products); and capital goods 26.2%.

Unfortunately, no attempt could be made to indentify the energy-intensity of each of the three components of the simulated manufacturing pattern.

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[1] The basic assumption in this scenario is that the whole is not merely the sum of the products of each individual, but an alternative with a new economic size guaranteeing the extra advantages of large-scale production, with as a result that the advantages occuring from large-scale production increase with the growth in volume. See: "Status of Arab Industry and Future Concept for Arab Industrial Development up to the Year 2000 (Chapter V: Strategy for Future Arab Industrialization, para.2-3)," Fifth Conference on Industrial Development for Arab States, 16-20 November 1979, Algiers, pp.112-115.

THE PARTICULARITY OF THE INDUSTRY ENERGY RELATIONSHIP IN THE DEVELOPING COUNTRIES

Energy industry interdependence is observable in any economy. However, national levels of economic development and country-wide industrial and economic structures diffrentiate the pattern of energy production and consumption. They also determine the articulation of industry and energy in the developed and developing countries. The problem of energy in general and of the energy and industry interdependence cannot be separated from the general problem of economic underdevelopment. Energy is but one of the dimensions of economic and social underdevelopment. Energy-industry relationship has big implications for the energy consumption and production pattern. Historical factors have strongly determined the pattern of energy resource availability and energy consumption in the developing countries. Indeed, in the case of the Arab World, general underdevelopment implies either an underdevelopment of domestic energy sources - as in the case of all the Arab and other developing oil importing countries - or, adversely, an overproportional growth of a specific energy source, generally petroleum in the Arab and other OPEC member countries.

But it is on the side of consumption and demand that one can better identify the particularities of the energy problem and conditions of industrial, economic and social underdevelopment.

Energy,as well-known, is both an input to production and a consumer commodity. In the case of Arab countries, the energy use pattern illustrates the deformation of the economic structure both as a feature and as a result of underdevelopment. There is an evident relation between the distorted and insufficiently developed structures of an economy and its pattern of consumption most specifically the energy consumption. Indeed, the use and consumption of energy fit into a two-sided energy consumption; on the one hand, there is a subsistent sector which generally responds and in fact, under responds to the needs of therural population. Energy produced and used in and for the sector falls under the category so-called non-commercial energy. Statistics still fall short of this side of energy pattern despite recently increasing efforts to quantify the production of this energy and its economic effects.[1]

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[1] The Conservation Commission of the World Energy Conference worked out a report in which attempt was made to evaluate the supply and demand of both commercial and non-commercial energy in the developing countries. See in this regard the World Energy Conference, "Third World Energy Horizons, 2000/2020", report to the Conservation Commission of the World Energy Conference, Munich, Spetember 1980, Paris Editions Techniques Economiques, 1981.

On the other hand, we recognize another sector mainly oriented to the satisfaction of private and urban transportation, residential and productive uses of energy, basically petroleum, in the urban centres and in some cases in mechanized and modern agriculture. In this context, the energy being used is characterized as commercial, since it consists of petroleum (in few cases coal), a commodity which is totally integrated in international trade. In the countries of which they are producers, its use implies a renunciation to export it, while in other countries which are in doubt with petroleum, it has to import from the international market. What is common to the two categories of countries is that only a small share of this commercial energy is aimed to feed an industrial and productive sector generally at its beginnings. The bigger share of the energy is oriented to non-productive consumption and to limited circle of the population. Putting differently, this energy sector has for function more to support a consumption pattern imported and copied from the developed societies than to sustain the productive sectors in the developing countries where this pattern is being adopted.

Consequently, there is a specific imbalanced articulation of the indigenous and traditional energy which is primitively produced and used, and the petroleum energy which, even when locally available, introduced a foreign pattern of energy consumption in the Arab and the other developing countries. To the extent, energy pattern is dominated in the developing countries by petroleum locally produced or imported so as to sustain a pattern of unproductive and when not uneconomical consumption, it is difficult to admit the argument that the development of developing countries is as much constrained as determined by their oil-import bill, an argument foreworded by the World Bank and, strangely enough, hastily accepted by many people.

In the third place, in order to determine the articulation of petroleum energy mainly supporting the expansion of non-productive energy consumption and the global energy in national economy, it would be necessary to discuss the social economic objectives both of the production of energy and its consumption, particularly its volume and productive and non-productive uses.

Finally, by considering the allocation to production of both of local and imported energy, it would be possible to evaluate the economical character and degree of the pattern of energy and of energy use. Indeed, the optimal utilization of energy as a production input is the key to the understanding and the solution of the energy problem in any economy, more particularly in the developing economies.

PART TWO - ENERGY SAVING ACHIEVEMENTS BY THE WORLD INDUSTRY

1. ENERGY-INDUCED CHANGES IN INDUSTRIAL TECHNOLOGY

The adjustment rises in the price of energy compared with the price increases of other inputs has changed drastically the current economies of many industrial process. A recent study carried out by UNIDO.[1] indicates that in many instances, however, the current investment plans, rationalization programmes and research programmes of leading producers have been undertaken prior to this basic alteration in relative prices. Most of these programmes were formulated with the implicit assumption that the relative price of energy in the early 1980's would differ little from that in the early 1970's. Firmly committed to development programmes by mid-1970's, such enterprises were caught unprepared when this assumption proved to be highly erroneous. Many are just beginning to respond concretely to the new set of relative prices.

Relative prices have been liken to a glacial drift, "imperceptible in the short run, irresistible in the long run."[2] Structural adjustments will be slow in coming because (a) economies naturally respond slowly to changes in relative prices and (b) oil-product prices have risen much less sharply than crude prices. Recent calculations by the International Energy Agency show that the difference between short-term and long-term adjustments is considerable.[3]

In fact, savings in energy by the industrial sector during the 1970s typically exceeded those of other economic sectors. In 1978, when the real price of oil was falling in the United States, industry used only four-fifths as much energy per unit of output as it did in 1973. In comparison, the final energy consumption per unit of GDP dropped only 8 percent between 1973 and 1978[4] A similar pattern was noted in Western Europe where Government have put efforts to spur research in energy fields and to restrain energy consumption by households.

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[1] UNIDO, "World Industry in 1980," Vienna, United Nations, 1981. Document UNIDO.ID/269 (Chapter IV. Energy Requirements in the Manufacturing Sector, p.182).

[2] ADELMAN, M.A., "An Agenda for the Eighties: Decisions and Research," Paper presented to the International Association of Energy Economies, Cambridge, 23-25 June 1980, p.3 (cited in UNIDO, "World Industry in 1980").

[3] For example, a 1 percent rise in the real energy costs reduces energy demand by only 0.15 percent in the short run. In the long run, however, as the stock of capital assets is adjusted to the new price pattern, the same increase in the real price of energy will reduce energy demand by 0.45 percent. (International Energy Agency estimates presented at the XIth World Energy Conference, Munich 8-12 September 1980).

[4] International Energy Agency estimated as cited in The Economist, London, 13 September 1980.

Various components determine the total energy requirements of a product. One aspect of particular relevance is energy analysis in product design. A method to calculate the total energy requirement of a product is particularly appropriate when implying an advantageous recycling of materials from discarded products, since it results in a lower energy requirement.

Energy is involved in many different processes:

- first, energy is needed for the production of materials from primary and secondary resources;
- second, energy is required by the manufacturing processes;
- and third, it is consumed during the use of products (e.g. automobiles, refrigerators, TV sets).

It follows that analyses of these aspects of energy consumption and use are necessary in order to optimize the energy requirements of the intended process. The final objective of the combination of these processes- the production of materials and the manufacturing and the functioning of a product - is to satisfy a certain need. The designer has an important role to play in the mimimization of energy requirements. He sets up a list of requirements and determines how that function can be realized. Finally, he chooses the materials and the manufacturing methods to establish the form of the product.[1]

The production of materials from scrap requires less energy than their product from primary sources. Therefore, recycling of materials from discarded products is also desirable from the point of view of energy use. This is shown in the following table:

Table 1. Energy Requirements for Material Production

Material	From Ore (MJ/kg)*	From Scrap (MJ/kg)*
Aluminium	327.6[3]	11.52[4]
Steel	72.0[2]	25.56[1]
Cast Iron	28.8[2]	-
Copper	61.2[3]	9.72[4]

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[1] BRAAM, J., "The Relevance of Energy Analysis in Product Design," Applied Energy Journal, Vol. 7, No.4, Barking, Essex, U.K., December 1980, Applied Science Publishers, p. 263.

(*) 1 Mega Joule (MJ) is equal to 0.278 kilowatt hour (kwh), a unit of energy frequently applied.

2. THE ENERGY REQUIREMENTS FOR MANUFACTURING

Manufacturing is one of the major energy-using sectors of any economy. However, the few publications available concerning the energy requirements of various manufacturing processes[1] tend to be concise and not very reliable. Consequently, little is known in a quantitatively accurate sense about the precise energy requirements of the various manufacturing methods.

The energy used for manufacturing is determined by:

a) the direct energy used by the capital equipment,

b) the energy content of machines (the more products that are made on a machine, the lower is this input energy per product);

c) the energy requirements for transport and

d) indirect energy requirements (for building, lighting, etc.)

To determine the total energy required for the manufacture of a part, the energy use can be given per unit of manufacture; for example, the number of joules per cubic centimeter of cut material, in the case of steel or per kilogramme of cast product for aluminium.[2]

It is necessary, when rating energy consumption by industrial sector, to take into account the sectoral production pattern since this pattern may have a significant impact on energy needs. For example the same production value may be otained exclusively by steelmaking or electronics. It is obvious that the resulting energy consumption would be very different. The first case concerns an energy-intensive industry. Consequently, it is necessary to adjust ratings resulting exclusively from added value according to the energy intensity of industrial production.

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[1] DECROP, M., "Dépenses d'énergie comparée dans divers procédés de realisation de piéces métalliques," Hommes et Fonderies, December 1975, pp.19-24 (in French). Also: KELLOCK, B.C., "Energy Conservation in Manufacturing, Machinery and Production Engineering," July 7, 1976, pp.13-16.

[2] Thus, energy requirements for cutting steel is estimated at 0.0126 MJ/cm^3; in the aluminium manufacture, casting by Cupola method requires 5.148 MJ/kg. by the Cupola Method and 10.8 MJ/kg in electric furnace. The data for casting are corrected on the assumption that the mean output for casting aluminium is 70% product and 30% waste (mainly runners). (DECROP, M., "Dépenses d'énergie comparée dans divers prócedés de réalisation de piéces métalliques," op.cit.).

According to available data, the share of the non-metallic products group in energy consumption is typically about three times greater than its share in value added of all manufacturing. Paper and iron and steel are also relatively heavy energy users, as they are in the developed countries. The mix of products produced by one branch is obviously an important determinant of energy consumption particularly if the branch is still at an intermediate stage of development. This applies to chemicals and petroleum, for example, and would explain why the median value is less than that found for textiles, which is a comparatively advanced industrial branch in many developing countries.[1]

TABLE 2. SUMMARY OF ENERGY REQUIREMENTS FOR SELECTED COMMODITIES

COMMODITY	PRIMARY PRODUCT	ENERGY REQUIRED PER NET TON OF PRODUCT
Aluminium	Alluminium Ingot	244
Beryllium	Beryllium Metal	2
Cement	Portland Cement	8
Chlorine	Gaseous Chlorine	18
	Liquid Chlorine	21
Copper	Cement Copper	87
	Refined Copper	112
Glass	Glass Containers	17
Gold	Gold Bars	58,855
Iron and Steel	Steel Slabs	24
	Gray Iron Castings	34
	Carbon Steel Castings	42
Lead	Refined Lead	27
Magnesium	Magnesium	358
Nitrogen	Ammonia	39
Quartz Crystals	Manufactured Quartz Crystals	1,120
Silver	Silver Bars	1,474
Tin	Tin Lingot	120
Titanium	Titanium Sponge	408
	Titanium Dioxide	86
Uranium	Uranium Oxide	
	by Acid Circuit	766
	by Alkaline Circuit	1,123
	by Resin-in-Pulp Circuit	795
Zinc	Elemental Zinc	65

[1] UNIDO Document ID/269, "World Industry in 1980 (Chapter IV)," United Nations, Vienna, 1981, p. 196.

3. CHANGE IN ENERGY CONSUMPTION IN THE MANUFACTURING SECTOR

Information on the extent of changes in the manufacturing industry's energy requirements is limited. A UNIDO study recalls that, "in fact, most Governments began seriously to monitor the consumption patterns of individual industrial branches or of manufacturing as a whole only after the rise in energy prices. The available statistics for many developing countries are still too incomplete to permit a wide-ranging investigation."[1]

Subsequent changes in the manufacturing sector's energy requirements depend on a variety of factors operating at the branch level:[1]

First, a country's industrial mix is important. Higher ratio of energy expenditure to value are recorded when energy-intensive branches account for a large or increasing proportion of acountry's net output. This type of industrial mix may reflect national policy decisions made in the 1960's and 1970's or the the composition of domestic demand for industrial products.

Second, the rate of technological innovation has been uneven among the various industrial branches, although, before 1976, new production processes probably tended to be energy-using rather than energy-saving. Thus, the pattern of energy consumption is in a state of flux as the emphasis of innovation shifts from material-saving to energy-saving.

Third, production technologies in any given branch often permit energy to be replaced by other types of inputs and conversely. During periods when energy was cheap relative to other inputs, various producers may have tended to substitute energy for other inputs. These procedures recorded higher growth in energy expenditures than they now would with the present input prices.

Fourth, and perhaps most important, recent studies have suggested that energy use may be substantially altered by changes in tasks or patterns of consumption.[2]

The net effect of these factors, in addition to the rise in the relative price of energy, is summarized in the following table. In every case energy expenditures in manufacturing per unit of MVA rose between the periods 1963-1964 and 1975-1976, so that the ranking of industries according to this measure showed little change between these years. The ranking of wood products and non-electrical machinery fell mainly owing to modest rates of increase in their consumption of energy per unit of value added.

1/ UNIDO Document ID/269, "World Industry in 1980, (Chapter IV: Energy Requirements in the Manufacturing Sector)," United Nations, Vienna, 1981 pp.191-192.

2/ See PETROLEUM INTELLIGENCE WEEKLY, 21 July 1981.

TABLE 3. INCREASE IN ENERGY COSTS, BY MANUFACTURING BRANCH,[1] IN SELECTED DEVELOPING COUNTRIES [2]

Branch	1963-1964	1975-1976	Percentage Increase
Iron and steel	115,868	243,961	110.5
Non-ferrous metals	118,674	184,403	55.4
Non-metallic mineral products	104,619	158,391	51.4
Paper and paper products	87,962	145,130	65.0
Chemicals, refining and miscellaneous products of petroleum and coal	67,664	135,901	100.8
Textiles	39,133	59,081	51.0
Rubber products	32,332	51,520	59.3
Food products	38,357	50,473	31.6
Wood and cork products	45,164	49,182	8.9
Plastic products	32,636	45,961	40.8
Beverages	26,251	41,730	59.0
Metal products	22,012	28,688	30.3
Transport equipment	17,059	28,118	64.8
Furniture and fixtures	17,887	23,428	31.0
Leather, fur products and footwear	15,247	23,105	51.5
Electrical machinery	15,481	22,330	44.2
Non-electrical machinery	17,401	21,850	25.6
Professional and scientific equipment, photographic and optical goods	10,080	15,393	52.7
Wearing apparel	9,399	15,090	60.5
Printing and publishing	9,908	13,848	39.8
Tobacco	7,716	13,252	71.7

Note: Figures are averages over two-year periods weighted by the country's share in U.S. dollars in total MVA for each branch.

The most significant trends concern the more energy-intensive branches: iron and steel; non-ferrous metals; non-metallic minteral products; paper products and chemicals, refining and related products. Energy consumption in these five branches far exceeds the levels recorded in other parts of the manufacturing sector. Moreover, each branch showed very high percentage increases during the period, raising from 51 to 110%. These facts help to substantiate the opinion that changing energy costs have altered many of the basic economic principles on which producers of steel, chemicals or non-ferrous metals have traditionally operated.

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[1] UNIDO Document ID/269, "World Industry in 1980," op.cit., (Talbe IV.4), p. 191.

[2] Countries included in the sample are Australia, Austria, Canada, Czechoslovakia, Denmark, Finland, Greece, Ireland, Japan, New Zealand, Norway, Portugal, Spain, Sweden, United Kingdom and United States.

4. BRIEF REVIEW OF SAVING ENERGY IN IRON AND STEEL

The iron and steel industry has long been the largest single absorber of energy to developed countries. The energy intensity of this branch, measured as inputs of energy per unit of output, is also one of the highest. Iron and steel is the largest single energy-consuming industry of the world. In 1973, it accounted for about 11% of the total world energy consumption. Of the different stages in producing steel from ore, the maximum energy is consumed at the ironmaking stage.[1/]

Advances achieved in saving energy in steelmaking in Japan, suggest several means, including:

a) better gas recovery from the basic oxygen furnace

b) waste-heat recovery

c) re-using energy hitherto wasted in the water-quenching of coke[2/]

Specific consumption of iron and steel per unit of output of steel containing manufactured goods has decreased as consequence of technological progress and structural change in industry as well as of attempts to energy conservation. It has been noted that consideration would have to be given in the future to the use of technologies which are energy-saving.[3/] This trend may have negative implications as much for Arab gas-rich countries by reducing their energy-base competitiveness, as for the other Arab countries with scarce energy source.

Energy savings of over 35% per man-year anticipated in the United Kingdom[4/] suggest that during the 1970s, traditional steel economies underwent a substantial change. As in other fields (e.g. petrochemicals), the variable cost of feedstock and energy is becoming critical. Technical changes are introduced in response to a new input-pricing pattern. However, it seems that as the iron and steel industry enters the 1980s, there will be few radically new developments with energy-saving consequences but a persistent stream of small improvements.

[1/] DAS, GUPTA S., "Some Aspects of Energy Saving in Ironmaking," Materials Aspects of World Energy Needs, The National Research Council, U.S. National Academy of Sciences, 1980, p. 234

[2/] A coke dry-quenching CDQ system using inert gas, not water, to absorb heat from the coke as soon as it is discharged from the ovens saves significant energy. See: IRONMAKING AND STEELMAKING JOURNAL, No. 4, 1979, p.145.

[3/] Document ID/WG.363/4, 11 February 1982, report of the Second Working Group Meeting on Scenarios of the Iron and Steel Industry's Development, Estoril, Portugal, 3-5 February, 1982, p. 7.

[4/] U.K. Department of Industry, "A Preliminary Analysis of the Potential for Energy Conservation in Industry," London, United Kingdom Department of Industry.

Five areas may be distinguished in which tecnologies are expected to change in the next five to ten years:[1]

1. Energy Savings in Direct Reduction Processes

In the direct reduction process, gaseous reductant processes, namely the Hyl and Midrex were found to have greater industrial application. The natural gas consumptions have been reduced by about 30% to 35%. This has been achieved by using better burden materials such as pellets instead of ore and recovery as well as utilization of waste heat.[2]

SPONGE IRON

Direct reduction of iron ore to make sponge iron - which in turn becomes the raw material for electric furnace steel - is gaining ground in both developed and developing countries.[3] With capital costs only 60% of those for traditional blas furnace - basic oxygen furnace (BF-BOF) converter combinations, the approach is regarded as particularly suitable for developing countries moving into steel production for the first time.

Direct reduction plants are also claimed easier to operate because they involve no liquid metal handling, and because they avoid the infrastructure, environmental and operating problems associated with blast furnaces.

Demand for sponge iron relates to the supply and demand for scrap steel suitable for electric furnace steelmaking. Although scrap is traded internationally, sponge iron shipment presents technical difficulties. In this context, therefore, Arab countries should consider sponge iron and steelmaking plant in the first instance to satisfy local or regional demand. However, it seems likely that gas price rises, traditional steel makers will relatively lose ground and that by 1985, a large portion of world sponge iron output will come from plants exported in rich energy and/or iron ore countries. For the electric steel, the iron ore will be shipped increasingly to producers with low-cost gas and coastal sites suitable for deep water ports and direct reduction sites.

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[1] UNIDO Document ID/269, "World Industry in 1980," op. cit., p.202.

[2] DAS GUPTA, S., "Some Aspects of Energy Saving in Ironmaking," Materials Aspects of World Energy Needs, The National Research Council, U.S. National Academy of Sciences, 1980, pp.243-246.

[3] For a more detailed description including the different processes available for making sponge iron, See: UNIDO Document, "Progress Report: Industrial Utilization of Associated Gas," Vienna, May 1980, p. 121.

In the blast furnace method, the limit of energy efficiency has now been attained. Further savings on coke inputs could be made only by replacing it with fuels less abundant than coal. Direct reduction (DR) will be the main hope for the future. The name was devised when it was thought that the process would lead directly to steel. But it was developed to use gas or oil inputs as reducing agents rather than coke (using the Wiberg process of 1952) and is comparatively energy-intensive. Despite this drawback, DR is foreseen as a major type of ironmaking for the next decade. By 1990, a significant proportion of existing iron capacity will have been retired, and some million tons of new capacity will be needed world-wide. Four-fifths of the developing countries' effective steelmaking capacity to be added between 1978 and 1985 will be in nine countries of which two (Algeria and Saudi Arabia) are Arab oil-producing countries. Nearly all the new capacity to be found in oil-producing countries will be via direct reduction of ore and electric-arc furnaces. Elsewhere, the price of energy will be a major determinant of the spread of DR facilities. In the longer term, from 1985 to 2000, DR fuelled by natural gas may be affected by failing supply and some observers expect that this will encourage the use of nuclear power in DR plants.[1]

Apart from its energy intensity, DR is attractive owing to its lower capital costs, which are some 60% below those of conventional techniques, chiefly because ancillary facilities such as cooling and sintering plants are not needed.

Forty projects, representing some 40% of the capacity of 125 projects announced by different countries of the world which were analyzed by UNIDO, involved the use of direct reduction and 90% of these projects are located in countries with petroleum or gas processing.[2]

The process of direct reduction involves 40% of the world-wide projected production capacity. In 90% of the cases, it involves petroleum exporting countries with natural gas at their disposal.[3]

It should be noted that a restricted oligopoly of industrial companies from the developed countries possess the technical processes.

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[1] At present, Japan is the only country actively pursuing a nuclear steel making alternative, but even a pilot plant will not be built before 1990. See: INDUSTRIAL WORLD, February 1979, p. 27 (cited in UNIDO Document ID/269, "World Industry in 2000"), p. 202.

[2] UNIDO Document ID/WG. 363/2,"The Normative Scenario. Effects and Conditions of Realization," Second Working Group Meeting on Scenarios of the Iron and Steel Industry's Development, Estoril, Portugal, 3-5 February 1982, UNIDO document dated 25 January 1982, p. 6 (in English).

(The Normative scenarios is that in whcih the Resultant R_1 tends towards the implementation of the projects announced by the developing countries, that is, the installation of a new capacity of 116 million tons).

[3] Ibid, p. 18.

2. The Spread of Electric Furnaces will continue -

Not only capital costs for the construction of conventional blast furnaces higher, but the built-in energy value contained in scrap is better utilized by electric furnaces.[1] Even more economical will be plasma furnaces, which can produce steel at $400 per ton less than electric-arc furnaces and do not need particularly sophisticated installation or maintenance skills. These are thought to be suitable for initial installations in developing countries.[2]

3. Further Energy Savings are anticipated by using still other techniques -

Scrap, sponge iron and other charge materials (that is, materials entered into the furnace to create the steel itself) can be continuously melted in a shift furance, and the liquid metal will then flow into an electric-arc furnace for refining (Klockner-Youngstown Steelmaking as in the U.S.A.).

The use of turbines to collect power from the blast furnace (let out to ensure an even air pressure during forming) can also save substantial amounts of energy.

4. Foundries are Exceptionally Energy Intensive -

On average, a foundry uses six times the energy of a typical manufacturing plant employing the same number of people. Melting, material handling and heating air for ventilation requires energy,and a massive effort in conservation has been mounted on all these fronts.[3]

5. Energy-Saving in Blast Furnace -

Continuous casting also promises major energy savings. In this process iron from a blast furnace goes into the convertor to become steel, whence it is poured out directly as slabs ready for rolling instead of first being set as ingots which have to be expensively reheated before being made into finished plate or coil. Steel thus made is about 15% cheaper than that from

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[1] Metal Producing, June 1979, p. 44.

[2] Industrial World, August 1979, p. 24.

[3] In the 1980s, computers in foundries will assist in infra-red thermography, which shows the places in the plant where heat is escaping most. Objects losing heat show the thermal (infra-red) energy radiating from their surfaces. As 30% of the heat consumed by furnaces can be lost from surfaces by radiation, the cost of the device is quickly recovered. See: Foundry Management and Technology, March 1979, p. 80 (cited in UNIDO Doc. ID/269, "World Industry in 1980," op.cit., p. 203).

more traditional fuels.[1] The 1970s marked the turning point for the acceptance of continuous casting as a legitimate breakthrough in steelmaking technology.[2]

The coke consumption in the blast furnaces has reduced by 25 to 55 percent between 1960 and 1976. This has been brought about by technological improvements such as the use of enriched ore feed, closer sizing of burden materials, higher usage of agglomerates, higher blast temperature, oxygen enrichment of blast, auxiliary fuel injection and higher top pressure. Use of pre-reduced material produced from plant wastes has also helped in lowering the coke rate. Besides, increases in the furnace size have also brought some savings in energy consumption by reducing the heat losses.

Use of higher top pressure in blast furnaces requires supply of blast at higher pressure and this in turn results in increased energy inputs. About 25 percent of the energy consumption in blowers can be recovered from high top pressure furnaces.

Efforts in energy saving in ironmaking are continuing and it is expected that by the mid-1980's coke rates of about 400 kg. per ton hot metal may be achieved in countries like Japan compared to coke rates of 430 to 600 kg per ton obtaining in the principal steel producing countries of the world.[3]

1/ Japan appears to be the leader in this development; between 1973 and 1980. The proportion of steel continuously cast rose from 20% to 47%.

2/ METAL PRODUCING, June 1979, p. 58.... However, UNIDO estimates that the high capital cost of replacing existing casting systems in steel works may limit the rate at which casting is introduced and will tend to restrict its application to new "greenfield" sites.

3/ DAS, GUPTA S., "Some Aspects of Energy Saving in Ironmaking," Materials Aspects of World Energy Needs, The National Research Council, U.S. National Academy of Sciences, 1980, p. 243.

5. ALUMINIUM INDUSTRY AND ENERGY

Aluminium and energy are closely related and as it is well known, large quantities of electricity are consumed in the prdocution of the metal. In U.S.A., discussion over governmental stockpiling of aluminium for strategic purposes, the point is often made that aluminium stockpiles represent stockpiles of energy.

As a consequence of the oil price corrections in 1973, the international aluminium industry has been forced to change its industrial structure and energy conservation, in particular, has become essential.

The aluminium industry, one of the typical energy-consuming industries, was seriously affected by this structural change. At the same time, in Japan[1] aluminium has come to be regarded as an effective weapon in contributing to the Japanese economy through resources and energy savings. Therefore, semi and tertiary fabricating industries increased their business operations.

Power sources by type for the world primary aluminium industry are: hydroelectric 51 percent, coal 14 percent, natural gas and oil 12 percent, nuclear 4 percent and other sources and information -not-available accounted for 19 percent. Information of power sources in the central economy countries is especially sparse.

In the USA, 14 percent of primary aluminium production capacity in 1979 used natural gas or oil, but this source accounted for 50 percent of Asia's capacity.

Energy sources for the aluminium industry in 1979 are shown in Figure 1. In the USA, 38 percent of primary aluminium production capacity used hydroelectric power, 41 percent used coal or lignite, 14 percent used natural gas or oil and 7 percent nuclear power. Smelting accounted for 70 percent of the aluminium industry's energy consumption. Processing of alumina and bauxite accounted for 11 percent and fabricating accounted for 19 percent.[2]

What is likely to be the pattern of power sources for the aluminium industry 10 to 20 years in the future? Any attempt to forecast any industry is fraught with uncertainties, but to forecast energy pattern is even more uncertain because of the intertwinning of numerous international, political, economi, strategic and social variables. Nevertheless, countries like the USA which are rich in coal and to a lesser extent in nuclear fuel reserves, but

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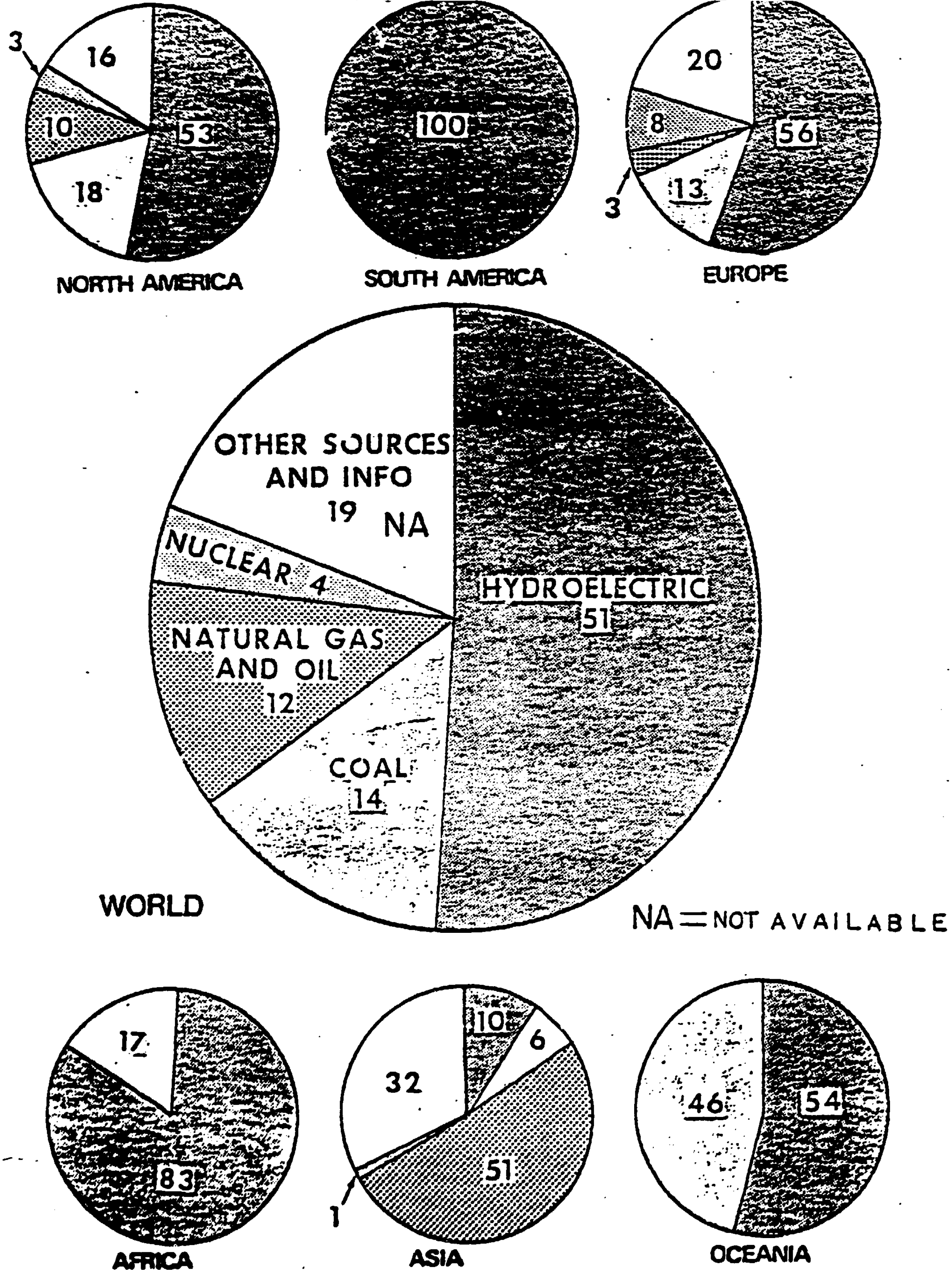
[1] In the Japanese smelting industry, petroleum-based thermal power accounts for about 70 percent of its total energy consumption. See: NAKAYAMA, Ichiro (President, Japan Light Metal Association), "Present Status of Energy-Saving in the Aluminium Industry in Japan," First International Aluminium Congress, Metal Bulletin Ltd., Madrid, 1980, pp. U(1)-U(2).

[2] HEINDL, R.A., (U.S. Bureau of Mines) "Aluminium and Industry," First International Aluminium Congress, Madrid, Metal Bulletin Ltd., 1980, p.B(1).

WORLD ALUMINIUM PRODUCTION CAPACITY BY TYPE OF POWER (PERCENT) [1]

(Figure 1)



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[1] "First International Aluminium Congress," Madrid-1980, Metal Bulletin Ltd, p. B(12), Figure 2.

whose energy consumption is largely dependent on increasingly imported oil and gas, are seeking to increase their use of coal and nuclear power. In Canada, hydropower will continue as the only significant power source, while Africa will depend almost entirely on hydropower. To the contrary, in the Arab countries largely endowed with oil and gas, such as the Untied Arab Emirates and Dubai, associated gas will continue as the only significant power source to the aluminium industry. In other countries endowed with hydropower, such as Egypt or Syria, hydroelectricity could sustain the developing of such an industry. However, one aspect of the aluminium industry is that, depending on the geographical area, the industry may bring out its own limits. For example, a smelter may be constructed in an area with readily available hydroelectric power (or even gas associated with a small or a depleting crude oil deposit). As time passes, either the population of the area increases because of the presence of the aluminium industry and aluminium consuming industries, or other industries are attracted by low-cost hydroelectric (or gas-based electricity) power. Ultimately, demand approaches generating capacity.

Aluminium production is power-intensive. It is not labour-intensive. As a result, when power generating equipment is being used at near-capacity; the price of power is likely to increase and marginal increases in power-production capacity are used to encourage development of labour-intensive industries, with the result that the cost of power to the aluminium industry is likely to increase, or power may become unavailable. Under such conditions, changes on energy costs can significantly affect the entire U.S. aluminium industry.

The increase in energy cost also accelerates the utilization of aluminium as an energy saving material, and the demand for aluminium metal will be expanded steadily from now on. The development of application technology of aluminium in new fields and the exploitation of new markets are becoming more important.

Following the 1973 oil price increases, the U.S. Bureau of Mines(*) commissioned a study to determine the energy use patterns in metallurgical and non-metallic mineral processing.

(*) through a contract with Battle Colombus Laboratories.

TABLE 4. ENERGY REQUIREMENTS OF ALUMINIUM PRODUCTION

	Unit	Units per net ton of aluminium	10^6 Btu per unit	10^6 Btu per net ton of aluminium
Reduction				
Makeup cryolite (Na_3AlF_6)	net ton	0.035	155.0	5.44
Cryolite transportation (300 miles by rail)	net ton-mile	10.5	0.00067	0.01
Makeup aluminium fluoride	net ton	0.02	51.4	1.02
Aluminium fluoride transportation (300 miles by rail)	net ton-mile	6.0	0.00067	0.00
Fluorspar (CaF_2)	net ton	0.003	1.59	0.00
Electrical energy (including ancillary)	kwh	16,000.0	0.0105	168.00
Total (reduction)				174.47
Total				243.90

TABLE 5. SUMMARY OF ENERGY REQUIREMENTS OF ALUMINIUM PRODUCTION

Stage	10^6 BTU per Net Ton of Aluminium
1. BAUXITE MINING AND TRANSPORTING	4.79
Share of Transporting	(2.38)
2. ALUMINA PRODUCTION	42.60
Share of Digestion	(21.50)
3. ELECTRODE MANUFACTURE	22.04
Share of Raw Petroleum Coke	(12.75)
4. ALUMINA REDUCTION	174.47
Share of Electric Power	(168.00)
TOTAL	243.90

Battle, in phase 8 of its report, entitled, "Opportunities to Improve Energy Efficiency in Production of High-Priority Commodities Without Major Process Changes", notes that, whereas U.S. industry average is around 8.0 kwh/lb. of aluminium, the more efficient U.S. plants have reduced this to about 6.5 kwh/lb. The pilot commercial installation of the Alcoa Smelting Process, which came onstream in July 1976, uses less than 5 kwh/lb of metal produced. The process produces aluminium by the electrolysis of aluminium chloride.[1]

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[1] Incidentally, in June 1979, ALCOA reduced the operating rate of the plant, located at Palestine, Texas, by one-half to 7,500 + py, while improvements are being made on the chemical segment of the plant. The modifications are expected to take 3-4 years to complete.

1. ENERGY-SAVING IN SMELTING, EXTRUSION AND FOUNDRY INDUSTRIES

1.1. Smelting Industry

In the smelting industry, dependent on expensive petroleum-based thermal power, reduction of unit power consumption has been the main subject of technology development. Thus, in the Japanese smelting industry power consumption at the smelting process has improved by 4.6 percent during the six years 1973-7979, while oil consumption at the alumina process has improved by 15.6 percent. Overall energy consumption for the production of primary metal was improved by 6.1 percent in the Japanese smelting industry.

In the following table, energy consumption in a Japanese smelting, at present and in the future is shown. The power consumption figure for the reduction process, in particular, is reaching the practical limit of 12,500 kwh/ton of aluminium.

Table 6. EXAMPLE OF RECENT ENERGY CONSUMPTION IN FIGURES AT SMELTING AND ALUMINA PROCESSES 1/

I. SMELTING PROCESS (130 KA PB E-E, OPEN POJ)

UNIT CONSUMPTION	YEAR 1979	1985 TARGET	REFERENCE 1973
Power (D.C. kwh/+ Al.)	13,600	12,800	14,900
Anode (Net kg/+ Al.)	450	430	500
Fluorides (kg/+ Al.)	20	20	32
Metal Purity (Al. %)	99.86 (Fe 0.10%, Si 0.04%)		

II. ALUMINA PROCESS (360,000 Million Ton per Annum)

	YEAR 1979	1985 TARGET	REFERENCE 1973
Caustic Soda (kg/+ Al_2O_3)	80 (*)	80	72
Steam (kg/+ Al_2O_3)	1,330	1,200	1,485
Bunker C Oil (l/+ Al_2O_3)	90	80	109
Power (kwh/+ Al_2O_3)	190	140	201
Impurities	(Na_2O 0.36) (SiO_2 0.010) (Fe_2O_3 0.005)		

(*) Due to deterioration of Bauxite quality, mainly increase of reactive silica.

1.2. Sheet Rolling and Extrusion Industry

Energy sources at the sheet rolling and extrusion industry of Japan are electric power, Lumber C oil, kerosene, LPG and city gas, the proportion being 50-55 percent for power, 45 percent for bunker C oil and kerosene and 5 percent for gases. The operating rates of sheet rolling and extrusion facilities have decreased between 1973 and 1979 after the oil increases due

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1/ NAKAYAMA, Ichiro, "Present Status of Energy-Saving in the Aluminium Industry in Japan," op.cit., p. U (11).

to a decline in demand. Under these deteriorating conditions, energy saving efforts have been pushed actively. Energy consumption per ton of product of 5.54×10^6 K cal. in 1973 was lowered to 4.85×10^6 K cal. in 1979, realizing a 12.5 percent reduction.

1.3 Foundry Industry

In the foundry industry, the percentage of each energy cost to production cost has risen as follows:

	POWER (%)	GAS (%)	OIL(%)	TOTAL(%)
Die Casting	1.3	0.9	0.8	3.0
Other Casting	1.6	0	4.0	5.6

In the casting industry, Japan realized 15-17 percent energy saving during the three years 1978-1980.

The oil price corrections seriously affected the aluminium industry in developed countries. Since 1973, it has been doing all-out efforts for energy saving and for cutting down production cost. And studies on switching energy source, especially from petroleum to other energy sources, particularly coal, hydropower, nuclear, are also being made.

The improvement in energy requirements from 8 kwh/lb. of aluminium to 6 + kwh/lb. in the U.S.A., was the result of both physical and operational changes in the Hall/Heroult equipment and procedures. These changes include the following:

1. Increase in capacity of Hall/Heroult cells up to 100,000 amperes and reduction of current density.
2. Reduction of anode and cathode resistance by more efficient design.
3. Redesign of busbar layout to minimize electromagnetic-induced turbulence in the metal/flux interface.
4. Improved operational procedures to increase efficiency; for example, increasing conductivity of the electrolyte with additions of lithium fluoride and improved control of temperature as near as possible to the liquids of the flux.

The study undertaken by Battle notes that, unfortunately the modifications increase capital costs markedly. In fact, the costs are such that it is not economical to make such changes in existing plants; they can only be made in new plants or new additions to existing plants.

Innovative technology for energy saving has yet to be established, but the improvement of present technology of production is taking place continuously in operation control and in production facilities. Rising energy costs give higher returns on investment for improvement and accelerate technology development.

2. ENERGY SAVING IN ALUMINIUM PRODUCTS

Lightweight, relatively strong, easy to fabricate, rust-free, etc.- these characteristics of aluminium are effective in energy saving. Recent experience confirms great possibilities of energy saving resulting from the use of aluminium products in railway cars,[1] railway cars for bullet trains, subway cars[2] and automobiles.

2.1. Present Status of Aluminium Utilization

After the oil price increases, resources and energy savings became one of the biggest issues facing the automobile industry throughout the world. Regulations governing exhaust gas and noise emission were adopted and targets of energy saving for automobiles set. Intensive efforts are being made by the automobile manufacturers to develop technology to meet energy saving targets. Utilization of aluminium is one of the effective measure to reduce car weight. Aluminium usage for typical small-size cars was 29 kg in 1979 in Japan and was expected to be 37 kg in 1980. At present, aluminium usage for cars is mainly for cast products such as engine-related parts, and is very limited for sheet and extrusion products. But aluminium wheel production has increased sharply in the past few years. Demand has increased tremendously and further market increase is expected in developed car-manufacturing countries. The other major markets in this area are van body and flaps for trucks. In 1979, 83 percent of total production of van bodies for refrigerated trucks and dry van trucks in Japan was made of aluminium.

While the aluminium industry has substantial potential for energy conservation, extremely high capital requirements and low returns preclude installation of present best available technology. If best available technologies were in place today, consumption could be reduced about 20 percent, from 109,100 Btu per lb. of aluminium to 87,000 Btu, according to a study published in April 1980 by the U.S. Aluminium Association. It is believed that a potential additional 18 percent reduction to 67,000 Btu per lb. may be achieved as technology advances.[3]

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[1] Aluminium-made railway cars first appeared in Japan in 1962. Since then, about 1,400 aluminium railway cars had been manufactured by 1979 in Japan.

[2] Aluminium-made cars have been actively promoted in Japan. They operate at about 130 km. The main purpose in the use of aluminium for weight reduction of subway is power consumption saving. It is estimated that the power saving rate is about 90 percent of weight reduction rate. Aluminium-made cars are very effective in reducing power consumption, but at present manufacturing costs of these cars are higher than for existing models. However, since it can be assumed that the trend of power-cost increase will continue in the future, the economics of using aluminium cars will improve proportionately.

[3] The U.S. Aluminium Association, "Energy and the Aluminium Industry," April 1980.

3. RECYCLING

While energy-saving efforts that change the nature of aluminium-smelting technology are impressive in their cumulative impact, their effect is slight in comparison with the effect on total energy use of recycling end-products. Thus, the recycling of aluminium-bearing cans saves fully 95% of the energy used in obtaining aluminium from bauxite.[1]

The recycling of aluminium scrap within the smelter process itself also offers substantial energy savings per unit of output. While most of the scrap produced in an aluminium plant is recycled, the fact that 40% of the inputs are used in creating scrap output means that strenuous efforts must be made to maximize the utilization of scrap. In general, interest in EEC countries in recycling waste and scrap is concentrated on paper and plastics, since theproportion of aluminium in total waste is lower than in the United States, where the all-aluminium beverage can is ubiquitous.[2]

Energy requirement for secondary smelting is only 1/27th of that of primary smelting. Under present circumstances, effective recycling is very important. Establishment of appropriate recycling channels and recovery technology are seriously needed.

From the viewpoint of resource and energy saving, recycling of metal is an especially important issue particularly for developed oil-importing countries. Systems of recovery of market scrap and re-use of scrap metal need be set up, but this requires resolving economic and technological questions on scrap.

The Potential for Alternative Processes for Recovering Aluminium

The Battle study evaluating the BAYER Process showed that alumina production required 42.6 million Btu per ton of aluminium or 21.3 million Btu per ton of alumina. At present, with respect to alumina production, neither the wet processes nor electro-thermal processes appear likely to energy-saving alternatives to the BAYER Process.

1/ In 1976, the United States Bureau of Mines reported that 4 to 8 million aluminium-bearing cans had been recycled, 15% more than in 1975. See: REAY, D.A., "Industrial Energy Conservation, Pergamon Press, Oxford, 1979, p. 62.

2/ In the United Kingdom, 73% of the aluminium produced is obtained from scrap, whereas in the United States, the aggregate figure is only 20%. See: HENSTOCK, M.E., "Second Recycling World Congress - resources report," Resources Policy, September 1979, p. 222. Also: "The Glass Container Industry and the Environmental Debate," report by the Gas Industry Liaison Working Party to the British Glass Manufacturing Federation, London 1977, p. 37.

4. ENERGY CONSERVATION IN THE AMMONIA INDUSTRY

Food and with it, fertilizer availability is one of the major problems facing most developing countries. Their Nitrogen demand, estimated at 18.1 million tons of N in 1980 is expected to rise up to 55 million tons in 2000. In the case of Arab countries, the Nitrogen industry is largely export-oriented, but has a tremendous potential home market that is critical to structural and production reforms.

Although nitrogen in its free form is very abundant in the atmosphere, roughly 8 G J must be spent in order to fix the necessary amount of nitrogen needed to give a good crop on one hectare.[1/] So it is no wonder that the whole history of the ammonia industry is a history of energy efficiency and so is its future, too.

Despite continuing efforts to find radically new methods of producing chemically combined nitrogen, no economically nor technically superior industrial method to chemical synthesis can be seriously said to be in prospect yet.

The sixty-year old ammonia synthesis process was the first industrial high pressure catalytic process converting large amounts of energy. Starting from an overall thermal efficiency well below 20 percent, with over 90 G J/ to N through a steady and spectacular technical development, it reached in the fifties a high technical level at 66.68 G J/ to N, and an efficiency considered as very high by that time. In the early 1960's, a revolution in the ammonia plant design took place with the introduction of the large scale single stream integrated flowsheet with a very high degree of energy recovery. The energy consumption fell to 44-45 G J/ to N corresponding to an efficiency of around 50 percent.[2/]

Until a few years ago it was taken for granted that a modern ammonia plant to be economic must be as stated above: large scale, single stream, integrated with maximum heat recovery and based on steam reforming of natural gas. Today, over a hundred plants all over the world have been built to the "classic" process scheme described and most of them with great success. Nevertheless some bitter experiences especially in several developing countries cast a heavy shadow over this bright picture. Arab countries benefit from the feedstock availability and transportation facilities for their Nitrogen industries. However, low-on-stream factors, operational

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[1/] Some 77,000 tons over every hectare of the earth's crust.

[2/] HONTI, G.D. (VEGYTERV, Hungary): "Energy Conservation in Ammonia Plants," UNIDO, Technical Conference on Ammonia Fertilizer Technology for Promotion of Economic Cooperation among Developing Countries, Beijing, Pe People's Republic of China, 13-28 March 1982, UNIDO Document ID/WG.364/6, p.1.

difficulties, maintenance problems more than offset the potential economic advantages. So it seems highly interesting to examine not only the future improvement possibilities, but also whether the economic advantages of this process scheme could be severed from its undesirable features - big size and oversophistication.[3/]

The modern ammonia process by itself is simple, easily controllable and can be implemented in any size. The economic and energetic advantages of the process are largely independent of size. Only the specific investment cost of a smaller plant will be higher, but otherwise will not be less efficient.

Another aspect is the whole energy recovery system. First of all, there is a close relationship: the higher the energetic efficiency, the higher will be the specific investment cost - independently from the size of the plant. The difference is that for a big plant, even relatively small energetic improvements will result in big sum of money. So there is a big incentive to recover every joule. For a small plant, it will be easier to operate at a higher-on-stream factor but accepting somewhat a lower energetic efficiency.

Rising stream at medium pressure will only result in a higher energy consumption, but all the troubles with feedwater quality, boiler turbine and expansion valve operation will be eliminated.

The economics of ammonia production frequently base specific energy consumption figures and production economics on 330 days of uninterrupted operation at full capacity. But if frequent shutdowns occur, energy consumption will raise by 20 to 30 percent, a substantially higher figure than the whole benefit from a sophisticated heat recovery system.

[3/] HONTI, G.D., op.cit., p. 12.

CHANGES IN THE DEVELOPING COUNTRIES

Logically, the share of manufacturing in energy consumption varies according to the structure of or composition of the sector. As discussed in this report, certain industrial branches such as chemicals, iron and steel, non-ferrous metals and paper are shown to consume relatively high levels of energy per unit of value added. These branches make up a large part of heavy industry, while less energy-intensive branches (e.g. textiles, clothing, wood products) fall in the category of light industry. Heavy industry now accounts to about 50% of net manufacturing output in the developing countries, up from 33 percent in 1955.[1/] An accepted dictum of industrial growth is that, in developing countries, the share of heavy industry in manufacturing output tends to rise as industrialization progresses. As it does, the manufacturing sector becomes more energy-intensive. Although the use of energy is becoming more efficient, the energy requirements of the developing countries bound to rise as structural change continues.[2/]

Data on the pattern of consumption in the developing countries, at the branch level, are extremely limited. Consequently, the figures shown in the following table should be regarded with caution; they are not necessarily representative of the general pattern of energy consumption in developing countries.

TABLE 7. RATIO OF ENERGY CONSUMPTION TO VALUE ADDED BY MANUFACTURING BRANCH IN DEVELOPING COUNTRIES IN THE 1970s [3/]

Branch	Median Value
Non-metallic mineral products	5.08
Paper and paper products	1.50
Iron and steel	1.37
Textiles	0.91
Chemical refining and miscellaneous products of petroleum and coal	0.76
Food products	0.69
Plastic products	0.64
Beverages	0.50
Wearing apparel	0.28
Printing and publishing	0.24

[1/] In developed countries the share of heavy industry is now around 70%. See: UNIDO Study (United Nations, Sales No. E.79.II.B.3), "World Industry since 1960: Progress and Prospects," United Nations, Vienna, 1979, p.66.

[2/] UNIDO Document ID/269, "World Industry in 2000 (Chapter IV: Energy Requirements in the Manufacturing Sector)," United Nations, Vienna, 1981, p. 195.

[3/] Ibid., (Table IV.7).

According to recent estimates, industry (including construction and utilities as well as manufacturing) as a rule accounts for approximately 50% of all energy consumption, while transportation uses over 30% and the services and household sectors consume the remainder.[1] Industry absorbs somewhat less than one-half of a country's final energy consumption in low-income countries and a greater portion at higher income-levels.[2]

Most of the figures in the following table refer specifically to the manufacturing sector's share in total energy consumption. They suggest that the manufacturing sector accounts for the bulk of all industrial requirements from 30% to 45% of total energy consumption. Available estimates of the ratios of energy expenditures to Manufacturing Value Added (MVA) are too few to provide any impression of trends in the pattern of energy consumption over time. They indicate an extremely wide range and should be regarded with caution. The data suggests that several developing countries (Argentina, Brazil, India and the Republic of Korea), with relatively large and diversified manufacturing sectors have recorded ratios no greater than those in developed countries.[3]

TABLE 8. SHARE OF THE MANUFACTURING SECTOR IN TOTAL ENERGY CONSUMPTION IN SELECTED DEVELOPING COUNTRIES, VARIOUS YEARS 3/

Country	Percentage	Period	Relative Growth Rates (energy/MVA) a/
Algeria	...		4.34
Jordan (b,d)	48.5	1977	...
Saudi Arabia	...		0.40
Brazil (b)	40.9	1976	1.00
Ecuador	11.0	1977	...
Guatemala	15.9	1977	...
India (b,d)	64.9	1977-1978	1.36(c)
Jamaica	48.3	1977	...
Mexico	41.0	1977	1.30
Republic of Korea	35.7	1974	0.89
Turkey	27.7	1977	...

(a) Data refer to all industry, which includes manufacturing, mining and quarrying and construction. Growth rates were calculated from data expressed in kWh and value added at constant prices.

(b) All industry.

(c) 1967-1976

(d) Electricity consumption only.

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[1] CHOE, B.J., HUGHES, Helen and LAMBERTINI, Adrian, "Energy Prospects for Developing Countries," Paper submitted to the Symposium on Industrial Policies for the 1980s, Madrid, May 5-9, 1980, p.19.

[2] UNIDO Document ID/269, "World Industry in 2000 (Chapter IV)," United Nations, Vienna, 1981, p.194.

[3] Ibid, (Table IV.6).

PART THREE - ENERGY AND INDUSTRIAL PROSPECTS IN ARAB COUNTRIES

1. PROJECT SURVEY AND DEVELOPMENT DIRECTIONS

Analysis of industrial projects completed in recent years, now under construction, or scheduled for completion in the near future in the OAPEC countries, covers some 1,400 projects for a total capital investment of 88 billion dollars.

Therefore, project analysis and additional information provide a fairly significant sample of the size and typology of investment undertaken since the middle of the 1970s in the OAPEC manufacturing industry.[1]

A preliminary summary of quantitative findings (limited to the number of projects and relative capital cost by country and sector) shows that in all the OAPEC countries and especially in OAPEC 3 the largest share of investment is in the basic sectors (Table 9).

Basic sectors are: refining (including lube plants), gas processing, petrochemicals and fertilizers (ethylene, urea, methanol, phosphate fertilizers), basic metallurgy (iron and steel, aluminium), and cement. These sectors account for 73.5% of total capital investment of the whole sample. In these sectors capital invested in the single projects is quite high, while the number of projects is limited because of their size.[2]

Light industry projects cover a larger share of capital in OAPEC 1 countries and in Algeria. In Saudi Arabia, information on light industry projects is much more detailed and complete than in other countries, however investments in basic industry predominate.

Additional data on industrial projects have been employed in order to estimate growth in production capacity for some key basic products over the 1977-85 period (Table 10).

OAPEC countries' capital and operating costs for major basic production have been analysed and compared with similar costs in the OECD countries. The results confirm that capital costs are much higher in the OAPEC countries (from 40% to 100%), while OECD and OAPEC albour costs are roughly comparable. Nevertheless, the lower cost of energy inputs in OAPEC countries is such that final product costs are competitive. However, the latter are not the only efficiency parameters.

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[1] "General Features of Main Industrial Projects in Arab Petroleum Exporting Countries," Development through Cooperation, The Interdependence Model, Seminar between OAPEC and South European Countries, pp. 149-152.

[2] Egypt is an exception. There are 77 projects in the refining sector for a total of approximately $1,400 million. But they concern essentially modernization and reorganization of existing plants.

TABLE 9. INVESTMENT COST AND NUMBER OF PRINCIPAL OAPEC INDUSTRIAL PROJECTS BY SECTOR AND BY COUNTRY 1/

(million dollars)	Refining and Gas Processing	Petrochemicals and Fertilizers	Basic Metallurgy	Cement	Sub-Total	Other Manufacturing	TOTAL
Algeria	2,500	1,376	500	750	5,126	5,675	10,801
Bahrain	400	300	300	-	1,000	50	1,050
Egypt	1,392	744	1,957	869	4,962	5,830	10,792
Iraq	4,200	3,000	630	1,481	9,311	1,723	11,034
Kuwait	500	720	-	-	1,220	90	1,310
Libyan AJ	1,218	3,500	4,150	610	9,478	1,656	11,134
Qatar	850	1,310	423	50	2,633	170	2,803
Saudi Arabia	12,495	8,575	680	1,486	23,236	6,174	29,410
Syria	433	556	-	944	1,933	1,565	3,498
UAE	3,250	800	1,850	135	6,035	515	6,550
Total	27,238	20,881	10,490	6,325	64,934	23,448	88,382
(percent composition)							
Algeria	23.1	12.8	4.6	6.9	47.4	52.6	100.0
Bahrain	38.1	28.6	28.6	-	95.3	4.7	100.0
Egypt	12.9	6.9	18.1	8.1	46.0	54.0	100.0
Iraq	38.1	27.2	5.7	13.4	84.4	15.6	100.0
Kuwait	38.2	55.0	-	-	93.2	6.8	100.0
Libyan AJ	10.9	31.4	37.3	5.5	85.1	14.9	100.0
Qatar	30.3	46.7	15.1	1.8	93.9	6.1	100.0
Saudi Arabia	42.5	29.2	2.3	5.0	79.0	21.0	100.0
Syria	12.4	15.9	-	27.0	55.3	44.7	100.0
UAE	49.6	12.2	28.2	2.1	92.1	7.9	100.0
Total	30.8	23.6	11.9	7.2	73.5	26.5	100.0
(No. of Main Industrial Projects)							
Algeria	4	16	1	5	26	149	175
Bahrain	1	1	2	-	4	17	21
Egypt	77	10	3	7	97	100	197
Iraq	13	4	1	14	32	109	141
Kuwait	1	2	-	-	3	7	10
Libyan AJ	2	12	2	5	21	36	57
Qatar	3	4	1	1	9	27	36
Saudi Arabia	13	8	1	6	28	619	647
Syria	3	2	-	12	17	69	86
UAE	3	3	3	2	11	35	46
Total	120	62	14	52	248	1,168	1,416

Source: ENI Estimates

1/ "General Features of Main Industrial Projects in Arab Petroleum Exporting Countries," Development through Cooperation, The Interdependence Model, Seminar between OAPEC and South European Countries, pp. 150-151 (Tables 1 and 2).

TABLE 10. PRODUCTION CAPACITY FOR SOME BASIC PRODUCTS: GROWTH ESTIMATES FOR 1977-1985 1/

	Refining thousand barrels/d.		Ethylene thousand tons/y		Methanol thousand tons/y		Ammonia thousand tons/y		Urea thousand tons/y		Iron - Steel thousand tons/y		Aluminium thousand tons/y		Cement thousand tons/y	
	1977	1985	1977	1985	1977	1985	1977	1985	1977	1985	1977	1985	1977	1985	1977	1985
Algeria	115	442	—	120	100	100	990	1,980	130	260	500	1,300	—	130	2,500	9,000
Bahrain	250	250	—	—	—	330	—	330	—	—	—	—	120	170	—	—
Egypt	285	410	—	—	—	185	570	1,400	900	1,390	1,740	2,700	100	170	3,800	9,500
Iraq	190	600	32	170	—	—	330	1,500	500	1,600	—	1,600	—	—	3,000	12,000
Kuwait	609	725	—	—	—	—	660	660	300	300	—	—	—	—	1,400	1,400
Libyan AJ	78	358	—	350	—	330	330	1,650	—	2,300	—	1,300	—	110	2,500	7,000
Qatar	10	60	—	280	—	—	330	660	330	560	400	400	—	—	340	540
Saudi Arabia	703	2,000	—	2,060	—	1,250	220	720	400	900	—	850	—	—	1,500	9,300
Syria	100	220	—	—	—	—	—	330	—	350	—	—	—	—	1,500	6,000
UAE	15	135	—	—	—	—	—	330	—	500	—	1,000	—	135	950	1,950
Total	2,355	5,200	32	2,980	100	2,195	3,430	9,560	3,060	8,760	2,640	9,150	220	715	17,490	57,290

Source: ENI Estimates

1/ "General Features of Main Industrial Projects in Arab Petroleum Exporting Countries," Development Through Cooperation, The Interdependence Model, Seminar between OAPEC and South European Countries, p. 152 (Table 4).

2. THE IRON AND STEEL PROJECTS

Available data suggest that in the Arab States per capita consumption of iron rose during the period 1970-1974 from 32 kgs to 65 kgs, that is at an annual rate of 15%. It is expected that this trend will continue, such that per capita consumption in the Arab States in 1985 will rise to 100 kgs. This rate is regarded low when compared with the consumption rates in the industrially advanced countries.[1]

According to the Gulf Organization for Industrial Consulting (GOIC), the total existing and planned iron and steel projects in the Arab Gulf States will represent only 30% of total regional demand estimated at about 16.4 million tons by 1995.[2]

Some Arab countries such as Jordan, already have an iron and steel industry and intend to expand it by constructing mini-steelworks.

On the other hand, Bahrain, Oman, the People's Democratic Republic of Yemen, Morocco and Saudi Arabia would be newcomers.

In the case of Qatar, Bahrain, Abu Dhabi, the projects entail production of sponge iron intended for export.

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[1] "Status of Arab Industry and Future Concept for Arab Industrial Development up to the year 2000 (Chapter IV. Trends in Industrial Development up to 1985)," Background Studies, Document 1, Fifth Conference on Industrial Development for Arab States, Algiers, 16-20 November 1979, p. 83.

[2] Statement by Dr. ALKHALAF, Ali-Abderrahman, former GOIC Secretary General at the GOIC Seminar on the "Strategy for the Development of Iron and Steel Industry in the Gulf Countries, Doha (Qatar), 17-18 March 1981.

Seven Arab countries are negotiating projects of more than 500,000 tons. These countries are Algeria, Egypt, Libya, Saudi Arabia, Abu Dhabi, Qatar and Oman. An additional project which remains to be negotiated for a "major" capacity is in Syria.

Six Direct reduction projects will be set up in the following countries: Egypt, Bahrain, Qatar, Abu Dhabi, Oman and Iraq.

Other six mini-steelworks projects are planned or under construction in the following countries: Morocco, Bahrain, Oman, Jordan, Syria and Democratic Yemen.

Finally, along with these projects under negotiations, Jordan is projecting an intermediate production capacity between 250,000 and 1 million tons.

TABLE 11. PLANNED CAPACITY AND TOTAL COSTS FOR IRON AND STEEL PROJECTS UP TO 1990 1/ 2/

Group	Country	Total Capacity (000t)	Total Cost (million US $)
I	Algeria	2050	4050
	Iraq	2050	4500
	Egypt	1565	2000
	Libyan Arab Jamahiriya	1250	3000
	Morocco	1210	1180
	Syrian Arab Republic	1180	2180
	Saudi Arabia	1035	750
II	Bahrain	430	250
	Jordan	402	375
	Abu Dhabi	400	200
	Qatar	400	200
III	Tunisia	225	250
	Oman	125	75
	Democratic Yemen	50	200
	Dubai	35	50

Group I	Above 0.80 Mill T capacity
Group II	0.25 Mill T - 0.80 Mill T capacity
Group III	Below 0.25 Mill T capacity

1/ Arab Countries planning no iron and steel projects include: Lebanon, Somalia, Sudan and Democratic Yemen, all with 0 T capacity.

2/ UNIDO Document ID/WG.356/4, "1990 Scenarios for the Iron and Steel Industry, "Special Dossier" - Iron and Steel Projects versus Indebtedness, Savings, Exports and Credit-worthiness," Third Small Expert Group Meeting on Scenarios of the Iron and Steel Industry's Development, Vienna, 26 November 1981, pp. 2-4 (Tables 1, 2 and 3).

3. PETROCHEMICALS AND ENERGY IN THE ARAB GULF

The key to the development of the petrochemical industry in the Gulf area has been the availability of two principal resources required, namely feedstocks and capital. It must be pointed out that the past and future petrochemical projects are all based on methane and ethane, hydrocarbons which would almost certainly be flared if they were not used for petrochemicals and other energy-intensive projects.

As a general rule, the Arabian Gulf states' investment selection is based on products with the greatest energy content and proportionately the lowest capital costs, since they gave the Gulf region the most comparative advantages.

For three products (namely ammonia, ethylene and methanol), it can be said that the Gulf enjoys a position in which the production is little more than half that of the U.S. [1/]

However, further downstream processing dilutes the economic advantage since it is aimed to obtain a mass production of general commodity products (e.g. low-density polyethylene), that are increasingly going through a process of devaluation with as a result, a stagnation or an actual cut in prices.[2/]

[1/] A production cost analysis of the production of 43,000 m t/yr ammonia from natural gas, indicates that the production costs of this product for the Gulf area, would represent 42% of those in the United States (7.07 compared to 16.9 U.S. dollars). In the case of ethylene, the figures would be 20.73 U.S. dollars in the Gulf compared to 38.64 U.S. dollars in the U.S.A. For methanol, the costs would be 5.64 U.S. dollars in the Arab Gulf and 18.53 U.S. dollars in the United States.

See: Gulf Organization for Industrial Consulting (GOIC), "Construction, Production and Distribution Costs of Petrochemical Projects," Doha, Qatar, 1979 and also: ALKHALAF, Dr. Ali-Abdul Rahman (GOIC), "Comparative Economics of Basic Industries in the Arabian Gulf Region, OAPEC Bulletin, Kuwait, July 1979, pp. 5-15.

[2/] For further details, see: EL-ZAIM, Issam, "Petrochemical Manufacturing Pattern and International Division of Labour, Components and Forthcoming Re-shaping," A contribution to the First National Congress for Joint Arab Economic Action Strategy, Baghdad, 6-12 May 1978, Secretariat General of the League of Arab States and General Secretariat of the Federation of Arab Economists (proceedings), pp. 699-726.

Also: EL-ZAIM, Issam, "A Re-evaluation of Petrochemical Joint-Venture and Technology in Petrochemicals," OPEC Review, Vienna, April 1978.

EL-ZAIM, Issam, "El Fomento de la Petroquimica en Qatar Permite a la Pequeña Compania Frances a CdF-Chimie Convertirse en une Empresa Multinational A Bajo Costo, "In Estudios de Asia y Africa (Quarterly), Vol. XIII, No. 3, Mexico, El Colegio de Mexico, pp. 375-396, (text in Spanish).

A joint UNIDO-GOIC study suggests that, assuming oil production rates at least equal to to those in 1980, known industrialization plans will certainly bring down the quanticites of gas wasted by flaring. In Bahrain, Kuwait, Qatar, Saudi Arabia, UAE, Libya and Algeria, resulting gas demand will be greater than the available supply from associated gas. Only in Oman, will there be a clear surplus that will still be flared unless some action is taken.[1]

Demand for gas in excess of supply will mean that some projects, especially those for LNG, will have to draw on non-associated source. This will not necessarily mean the end of flaring, however. In Syria, considerable investment would be needed to permit sole use of assoicated gas in preference to non-associated supplies.[2] In this context, attention is drawn to the results of a study carried out on economic usage of small quantity of gas flared at isolated wells.[3]

Attention is also drawn to the near universal use of the ethane component in associated gas streams for its fuel rather than chemical value. At best, e.g. in Saudi Arabia, only half the available ethane will be consumed by plants either planned or under construction. The remainder is extracted in LNG and LPG facilities or consumed as fuel and feedstock along with methane.

4. INDUSTRIAL USES OF ASSOCIATED GAS

After re-injection, the largest outlet for associated gas is direct export in [illegible] form of pipeline gas or LNG. The interest in industrial applications as an alternative arose partly from demands for industrialization per se, partly because the prices for export gas were considered too low to justify the investments involved in liquifaction and long-distance pipelines.[4]

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[1] UNIDO/GOIC: "The Industrial Uses of Associated Gas," op.cit. p.45.

[2] Instituto Mexicano de Petroleos carried out such a study. See also: RUI, R.W., "Production of Low Density Polyethylene from Ethane and Propane in Associated Gas Produced in the North-West of Peru," UNIDO 1980 (an internal document).

[3] UNIDO/GOIC, "The Industrial Uses of Associated Gas," op. cit. p. 47.

[4] "The Industrial Uses of Associated Gas (Chapter II. The Main Uses of Associated Gas, 1980 to 1985)," A joint study by UNIDO and Gulf Organization for Industrial Consulting, 30 April 1981, compiled in UNIDO Document, UNIDO/PC.11, 20 July 1981, p. 35.

The list of industrial products on which associated gas can be based is very large, even when confining it to products in which gas functions as a raw material rather than an energy source. UNIDO suggested a selection of these which were considered most probable in the next two decades, and which divides them into four groups:

1) Petrochemicals (Olefin and aromatics-based)
2) Fertilizers (ammonia-based)
3) Methanol (chemical and fuel uses)
4) Metals (sponge iron and ferrosilicon)

To this could be added a fifth group - petro-protein - initially based on methanol, later directly on gas-consuming microbes.

TABLE 12.PRODUCTS SELECTED FOR GAS UTILIZATION [a]

Ethylene	:	Algeria, Qatar, (Iraq, Kuwait, Libya, Saudi Arabia)[b]
Low-density Polyethylene	:	Algeria, (Iraq, Kuwait, Libya, Qatar, Saudi Arabia)[b]
High-density Polyethylene	:	(Iraq, Qatar, Saudi Arabia)[b]
P V C	:	Algeria, (Iraq, Kuwait)[b]
Ethylene dichloride	:	(Saudi Arabia)[b]
Ethylene oxide/ ethylene glycol	:	(Kuwait, Saudi Arabia)[b]
Styrene	:	(Saudi Arabia, Kuwait, Libya)[b]
Ethyl Alcohol	:	(Saudi Arabia)[b]
Ammonia	:	Algeria, Iraq, Kuwait, Libya, Qatar, (Bahrain, Saudi Arabia, UAE)[b] and Syria
Urea	:	Iraq, Kuwait,(Libya, Saudi Arabia, UAE)[b]
Methanol	:	Algeria, Bahrain, (Saudi Arabia)[b]
Aluminium	:	Bahrain, UAE (Dubai), (Algeria, Iraq, Kuwait, Libya)[b]
Sponge Iron	:	Bahrain, Qatar, Syria, (Libya, Iraq, Oman, Saudi Arabia)[b]

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[a] Excludes power generation, desalination, cement manufacture and general gasification of the economy.

[b] Planned or under construction.

4.1 ARAB INDUSTRIAL PRODUCTS BASED ON ASSOCIATED GAS

By 1985, nine Arab countries will be operating ammonia plants, and five of this downstream user units. Eight countries are building or planning direct reduction sponge iron plants as the basis of a local steel industry. Aluminium in contrast has six adherents.

Methanol, which like ammonia can use natural gas a feedstock without significant pre-treatment, will be produced in only three countries.

Despite the heavy upstream investment needed for ethane recovery, six countries are also embarking on petrochemical production with large ethylene crackers.

In downstream plastics, low-density Polyethylene, in six countries and high-density Polyethylene, in a single country, have the edge over PVC with three prospective producers. Only two countries are moving into ethylene oxide/ethylene glycol, and further three will set up styrene production on the basis of locally available benzene and ethylene.

Measured in terms of the number and diversity of projects, the leading Arab countries will be Saudi Arabia and Iraq. The least gas-oriented industries will be in Oman and Syria, both with only limited quantities of associated gas. The estimated capacities for gas-based industrial products in Arab oil producing countries are shown in Table

4.2. CHARATERIZING THE ARAB ALUMINIUM INDUSTRIES

The primary industry in the Arab area consists of three companies, the Aluminium Company of Egypt (EGYPTAL), the Aluminium Bahrain Company (ALBA) and the Dubai Aluminium Company (Dubai, U.A.E.). Of the three operations, Dubai is the only one which is a creature of the new energy era. It is not just a smelter but, through utilization of waste heat from its gas turbines, is capable also of producing some 24 million gallons of water per day. [1]

On the secondary front, the establishment of the primary producers has sparked the establishment in their home countries of downstream facilities for the production of cable, powder and rolled products on a little scale appropriate to their available markets. A more widespread feature has been the establishment of new extrusion plants throughout the area encouraged by the construction boom from mid to late seventies. In the Gulf of Arab States, these are now establishing multi-shift operations and moving toward or into profitability, although the extrusion business is not always market-protected.

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[1] LIVINGSTON, Ian D., (Dubai Aluminium Company Limited), "The Aluminium Industry in the Middle East Current Position and Future Prospects," Proceeding of the 'First International Aluminium Congress', Metal Bulletin Limited, Madrid, 1980, p. W(2).

TABLE 13. GAS-BASED PRODUCTION OF PETROCHEMICALS, FERTILIZERS AND SELECTED INDUSTRIAL PRODUCTS IN DEVELOPING COUNTRIES[1/]
(mid-1980s estimates - - ton/year)

	Ethylene	Low-density Polyethylene	Hihg-density Polyethylene	EDC/VCM or PVC	Styrene	Ammonia	Urea	Methanol	Aluminium	Sponge Iron
Algeria	140,000	48,000	-	35,000	-	991,000	278,000	100,000	127,000	800,000
Bahrain	-	-	-	-	-	660,000	-	350,000	120,000	400,000
Iraq	130,000	60,000	30,000	60,000	-	994,000	1,535,000	135,000	120,000	1,935,000
Kuwait	350,000	130,000	-	-	320,000	994,000	1,360,000	-	120,000	1,935,000
Libya	-	-	-	-	-	663,000	900,000	330,000	60,000	1,000,000
Oman	-	-	-	-	-	-	-	-	-	400,000
Qatar	280,000	140,000	70,000	-	-	595,000	991,000	-	-	800,000
Saudi Arabia	1,606,000	640,000	171,000	454,000	295,000	528,000	500,000	1,320,000	-	800,000
Syria	-	-	-	-	-	300,000	346,000	-	-	1,000,000
UAE	-	-	-	-	-	330,000	-	-	135,000	800,000
TOTAL										

1/ "The Industrial Uses of Associated Gas (Chapter II. The Main Uses of Associated Gas, 1980 to 1985)," A Joint Study by UNIDO and Gulf Organization for Industrial Consulting, 30 April 1981, compiled in UNIDO document, UNIDO/PC.11, 20 July 1981, Table 11, p. 46.

ENERGY ASPECT OF FUTURE PRIMARY ALUMINIUM INDUSTRY IN THE GULF ARAB STATES

The most significant development could be expansion of the primary sector, either by way of expansion of existing smelters or by the establishment of new installations. All the Gulf Arab States have the access to energy and to finance which are the most significant advantages of the area. However, they are handling many competing priorities and smelter development will not necessarily be among the most pressing or attractive of their available options. Large new plants will not be encouraged either by the new caution about rapid industrialization uncertainties. There would be considerable emphasis on manpower efficiency altogether, both for cost reasons and also for political reasons. This will in turn determine the specific future uses of energy and of its conservation in new projects.

Another element emphasizaing the need to optimize the energy use in the future projects is the increase in investment which will be necessary to provide a significant degree of infrastructure in most places where new projects are conceivable.

Finally, the standard of power operations in public utilities in developing countries does not always encourage dependance on a local grid and there would be a strong argument for smelters to have their power stations but with appropriate connections to the public system for reasons of mutual benefit and protection. In the case of the Arab World, steam turbines are becoming more popular for major installations but where gas turbines are used, it seems unlikely that these will be installed in future without waste heat collection systems. Early experience in Dubai indicates interesting possibilities for achieving very high thermal efficiencies through the sequential use of steam first in pass-out turbines and then at lower temperatures and pressures for desalination.

According to GOIC estimates, consumption of total aluminium in Arab Gulf countries was set at 178,000 tons per annum (1980) of which 171,000 tons consisted of Primary Aluminium. GOIC forecasts put Arab countries' aluminium consumption in 1985 at 351,000 tons of total aluminium and 334,000 of primary aluminium. The forecasts for 1990 are 591,000 tons and 547,000 tons respectively. By the year 1995, consumption of total aluminium would be of 952,000 tons and that of primary aluminium at 859,000 tons. The forecast growth rates for average annual consumption of total and primary aluminium were estimated, respectively at 6.8% and 6.3% during the period 1979-1995.

GOIC sizes primary aluminium demand in Arab countries in 1980 at 171,000 tons and supply at 314,000 tons leaving a surplus of 150,000 tons of primary aluminium. Between 1979 and 1985, Arab primary aluminium production is to increase, averagely at 13.0% annually, compared to 5.3% for the total world.

4.3 LIMITS OF ENERGY ADVANTAGES: SOME REMEDIES

ENERGY ASPECT OF UP-STREAM INTEGRATION IN THE GULF ALUMINIUM INDUSTRY

Up-stream integration is expected to occur following the establishment in the Gulf area of a petroleum coke manufacturing facility.[1] Indeed, such a project is being promoted by the Gulf Organization for Industrial Consulting. Instead of importing petroleum coke from the U.S.A. at about $60.00 per ton (1980), the Gulf industry which is operating at the epicentre of the world petroleum industry can do better by setting up a domestic petroleum coke manufacturing facility.

The development of other mineral and chemical industries in the Gulf and the wider Arab area will almost certainly prompt the production of aluminium fluoride and cryolite. This will obviously be encouraged by any growth in the primary sector. It is necessary therefore for Arab producers to anticipate the set up of R and D structures in the production of aluminium fluoride and cryolite.

On a longer projection it would not take much more development of primary capacity in the Gulf to justify the cooperative development of a source of alumina, although cooperation on that scale and complexity would probably be some half a dozen companies and governments. At that stage energy saving and conservation would be an important issue under such a cooperative scheme.

The accumulation of experience will make the area progressively less dependent upon imported technology. However, it is hoped that the Arab countries will cooperate in the area of technology and in energy saving and conservation. For that they will also need to develop new arrangements for technological cooperation and assistance with other aluminium industries, so as to maximize the energy, finance and geographical location advantages of the Arab aluminium smelting and manufacturing.

As the medium-term trend makes clear, the traditional large consumers of primary aluminium are becoming less sufficient. The reason is partly the changing energy base, which by itself has meant a dramatic review of the location parameters for primary smelters.

Given the intensive nature of aluminium production, it seems logical that many of the 20 smelters estimated as furtherly, needed to meet the increasing demand for primary metal, be built in countries where energy is abundant and gas is extracted associatedly with crude oil. In that sense, the use of associated gas in Arab oil producing countries that would otherwise be flared, would put them in an advantageous position.

Low-cost energy for smelter power is of course only one factor. Alumina may have to be imported. On the other hand, the Arab Gulf region has alumina clays that would not normally be considered for alumina refining. It may be feasible to apply more energy-intensive refining to such clay feedstocks, thereby avoiding the cost of shipping in ready-refined alumina.[1]

The biggest incentive to set up gas-based alumina production in Arab countries may prove, however, to be the changing energy picture elsewhere. It is no longer accepted that the international industrial power consumers should obtain energy at low rates, at the expense of domestic and commercial power users. On the other hand, the utility value of alternative energy forms - gas, hydropower, lignite, etc. - is being increasingly aligned to the heat equivalent value of oil, with as main consequence for the application of flared gas, is that the trend strongly favours the establishment in the Arab gas-rich countries of a primary aluminium industry which will have a growing economic advantage as time passes.

As with sponge iron, plans for gas-based aluminium smelters in Arab countries should be tempered with the consideration that both the raw material-bauxite and alumina-and large parts of the market for the product are in the hand of others.[2]

To avoid consequent external control of the value added, downstream cooperation will necessary reveal among Arab countries and other developing countries.

4.3.1. Energy Saving by Using Aluminium in Car Manufacturing: Issues for Arab Aluminium Industry

Energy saving through weight reduction using aluminium for car parts can be expressed on the basis of the total of production energy consumption (sum of energies for material production process and fabrication process) and fuel energy consumption. Aluminium substitution for steel contributes to a weight saving of 1.5 - 2.25 times and higher mileage is obtained by aluminium. Taking into consideration the recycling of aluminium parts, usage of aluminium contributes not only to energy saving but also to natural resource saving. The effect of weight reduction and longer life of cars through utilization of aluminium is becoming known among customers, especially the characteristics of light weight, anti-corrosion and ease of fabrication and, therefore, further aluminium substitution for car parts will be promoted.

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[1] UNIDO/GOIC: "The Industrial Uses of Associated Gas," UNIDO Document, UNIDO/PC.11, 20 July 1981, Vienna, p.93.

[2] UNIDO/GOIC: "The Industrial Uses of Associated Gas," op.cit., p.94.

Two policy issues can be identified in this connection:

a. For the Arab Gulf aluminium-producing countries which already envisage or are likely to later envisage expansion in aluminium downstream operations, they need to seize the opportunity by orienting their aluminium extensions or expansions towards the new and growing demand resulting from increased use of aluminium for car parts. The fact that the Gulf and several other countries are important car importers while exporting large quantities of oil, mainly to developed car-manufacturing countires, should stimulate new deals between the two categories of countries under which the first would supply the second not only with oil and gas, but also in aluminium products for use in car parts. The result could be an improvement of the therms of trade between these countries and their oil clients and car suppliers.

b. For the several Arab countries planning a car manufacturing industry, usch as Iraq, Algeria, Egypt and Saudi Arabia, it is most important that they consider energy-saving by using aluminium when adopting their final car manufacturing projects. They need to introduce these aluminium-based energy-saving manufacturing technologies as much as seeking to supply their future car manufacturing plants with aluminium products from neighboring Arab aluminium producing countries. This would contribute to reduce the economic risks of further Arab aluminium downstream expansions, when not enhancing their economic profitability, while increasing the articulation of industrial sectors and the integration of the whole economies of the Arab countries.

4.3.2. Energy-Saving by Using Aluminium in LNG Tanks Manufacturing

One of the consequences of the price rectification and the depletion of crude oil is the current structuring of a world-wide gas trade. Many Arab countries are fortunately endowed with natural and/or associated gas, and some of them, like Algeria, have been pioneer in promoting a remarkable export-oriented gas liquification industry. Today, it is admitted that one of the main alternative energy sources is LNG.

LNG stored at -162°C material for tank construction should have high performance characteristic at very low temperature. Aluminium (5083-0) has been utilized together with 9 percent Ni-steel and has proved to be a very reliable material. Since 1969, dozens of aluminium-made land LNG tanks were constructed and quantities of aluminium used, as dozens of underground (membrane tank) were constructed and significant quantities of aluminium were used in the suspension deck (roof). In order to cope with the increasing LNG demand in the future, further aluminium-made storage tank construction is expected. Efficient and safe transportation has been possible by LNG tankers equipped with aluminium alloy-made tanks. [1]

Arab countries can be considered gradually moving into aluminium-production land LNG storage tanks as well as LNG tankers. This could justify and stimulate expansion and diversification of the Arab gas-based aluminium industry, while supporting the development of Arab LNG export activity and ensuring better its integration with industry and national economy.

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[1] From 1969 to 1980, 18 aluminium-made land LNG tanks were constructed in Japan and about 11,000 tons aluminium used, while 23 underground (membrane tanks) were constructed and about 480 tons aluminium were used in the suspension deck (roof).

5. THE CHALLENGE OF LONG-TERM ENERGY-RELATED TECHNOLOGICAL BREAKTHROUGHS

In so far as energy sources are concerned, it is assumed that in the period 1980-2000, fossil fuels, in particular oil and gas, will continue to be the main energy source available for use in industrial development.

It is anticipated, however, that increasing consumption of petroleum-based energy, will stimulate in the next 20 years efforts to substitute or add new oil and gas resources to those which will be outstripped in all the Arab oil-producing countries.

Further, the prospects of petroleum depletion in these countries and the absence of significant resources in the other Arab countries, will justify and sustain a strong drive for substitutes, oil and gas, that will be made available particularly hydropower, solar, nuclear and biomass as well as coal whenever possible.

Still, there is another factor which will act to diversify while, transforming, the global Arab pattern of energy production and use during the 1990's and beyond. Effectively, energy-related technological breakthroughs are actively sought by the international industry to dramatically cut down energy inputs in industrial products. Although such breakthroughs are unlikely to occur before 1990 or 1995, they should neither be excluded nor under-estimated by Arab industrial planner when forecasting the future position of the new or planned projects. Many of them can be foreseen and their impact on the economics of industrial production and on international markets expected. To the extent Arab industrial projects are increasingly export-oriented, these energy-related technological breakthroughs may totally threaten the future of these projects by the time Arab efforts would have brought them to a stage of internal consolidation.

It follows that Arab countries seriously need to plan and prepare alternative sources of energy in connection with future industrial patterns and to be very attentive to forthcoming technological breakthroughs, while endeavoring to achieve similar innovations in energy-related technological breakthroughs and in their consecutive industrial processes and patterns. This fundamental issue is as much of energy-essence as industrially-oriented. Its magnitude and gravity call for a planned and systematic cooperation among Arab countries in order to tackle it successfully and thus ensure the future of forthcoming generations.

The recent upsurge of interest stems from the establsihed advances in catalysis that are available to chemists in playing with these base-molecules for engineering more complex ones like hydrocarbons.

The methanol route to olefins and high-aromatic gasoline has already determined a lot of research into zeolites for a proper exploitation of their "shape-selectivity".

As for other alternative chemical feedstocks, although chemical enterprises are becoming increasingly interested in "life-sciences", the exploitation of renewable resources will be a long way down the road.

However, biotechnologies may well develop more rapidly through fundamental and applied research activities concerning "genetic engineering".

Quite a number of oil and chemical companies are already involved in it. Of course theopenings for developing revolutionary technologies as well as the recent attainments regarding several exciting products having high growth potential (e.g. human insulin, human growth hormone, interferon), largely account for such a crowd participation.

Several ambitious projects aim at engineering micro-organisms which may well modify, selectively, specific substrates for the obtainment of primary and secondary energy vectors and a large variety of organic chemicals, (e.g. H_2, CH_4, MeOH, biopolymers, food fortifiers, drugs).

These are only a few of the major challenging objectives that are currently being pursued by international energy and chemical industries as well as public organizations epitomizing the evolutionary pattern of science and technology.[1]

No major technological change seems imminent in any of the stages of aluminium processing. The Bayer process for alumina production is already highly efficient, although meodest energy savings may be obtained by improving the electrolyte and cathode materials used.[2]

For the electrolysis of alumina in the smelting of aluminium, most analysts expect the conventional Hall-Heroult method to be in use at least until the end of the century.

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[1] CERNIA, Enrico (Assoreni, Italy), "New Frontiers in Science and Technology," Development Through Cooperation, Proceedings of the Seminar Between OAPEC and South European Countries, Fourth Session, pp. 162-163.

[2] Even if the process were not particularly energy efficient, the fact that bauxite is transformed into a much lighter (by half) and more readily transported material would tend to diminish the urgency of technological change at the site of the bauxite mine itself. Only a small volume of cooperant inputs (soda, chiefly) are required at this stage. See: BRUBAKER, S., "Trends in the World Aluminium Industry," Baltimore, 1967, John Hopkins Press, pp. 163-172.

New methods (e.g. sub-halogenizing or carbothermic smelting) are not economic.1/ Although the ALCOA Process, when fully operational will require 30% less energy than the Hall-Heroult method.2/ The major attraction of the Alcoa Process, which will require several years additional research, is its small economics of scale. Small-scale alumina importers will be able to operate economically.

In the long run, the use of nuclear energy, either converted to electricity or supplied to the steelworks directly in the form of heat, is likely to greatly influence steel production. In order to be fully effective, the iron ore would have to be reduced using gas, rather than being melted in a blast furnace. Difficulties also exist in balancing the demand for the heat and electricity ouput of the reactor complex.3/

"... Whenever the use of new and renewable sources of energy is dependent on highly sophisticated and non-conventional technology, the mobilisation of such sources in the developing countries, without the mastery of the technologies involved, will result in a greater dependence on the suppliers of such technologies and the corresponding equipment. In this connection, ... for the creation of a centre to promote technological development and application of new and renewable sources of energy in developing countries... a .. proposal was included in the UNIDO study "Industry 2000", at the suggestion of a group of eminent personalities when preparing for UNIDO III." 4/

1/ METAL BULLETIN (Monthly), April 1979 and GYFTOPOULOS, L. J., AZORIDIS, L. J. and WIDMER, T.F., "Potential Effectiveness in INdustry," Cambridge, Mass., Ballinger 1974, p.72.

2/ METAL BULLETIN (Monthly), July 1977, p.45.

3/ Several studies are being undertaken based mainly on the High Temperature Reactor (HTR), which uses helium as the reactor coolant, but any applications are unlikely before 1990 and benefits are therefore of a very long nature. One possible site layout, based on the HTR system is suggested by the U.K. Institute of Physics for the use of nuclear heat in steelmaking from sponge iron produced by the gas-reducing of iron ore in metallizing shaft furnace. See: REAY, D.A., "Industry Energy Conservation (Chapter 3: The Energy Intensive Industries," Newcastle-upon-Tyre, England, 1979, p. 59.

4/ Statement by Dr. Abd-El Rahman Khane, Executive Director of UNIDO at the United Nations Conference on New and Renewable Sources of Energy (UNCNRSE), Nairobi, Kenya, 10-21 August 1981, para. 9.

If the Arab industrial planners and decision makers want to minimize the energy requirement of their potential products, they need to obtain from the engineering and construction companies entrusted with the design and construction of future production plants, the amount of material that can be recovered from the discarded product within the design.[1]

Industry has made progress in energy conservation and savings through technological innovations. At the same time, there is a clear evidence that the demand for energy will steadily grow, largely because of the developing countries' industrial aspirations. As world demand climbs, the need for a more equitable international distribution of supplies becomes more pressing. Under these conditions the desirability of more rapid advances in energy conservation, coupled with the equally rapid transfer of these technologies throughout the world's industrial sectors, can hardly be denied. [2]

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[1] The energy saving associated with the recovery of materials in a genralized situation has been calculated first by Berry and Fels for BERRY AND FELS for the manufacture of automoible from the automobile scrap, then, more recently by BRAAM for the comparison of energy used, in manufacturing hexagon head bolts by extrusion, and the energy commitments involved in substituting aluminium alloys for steel and cast iron parts in automobile.

See: BERRY, Stephen R. and FELS, Margaret F., "The Energy Cost of Automobiles," Science and Public Affairs, 11 Dec 1973, pp.11-17 and 58-60.

Also: BRAAM, J., "The Relevance of Energy Analysis in Product Design," Applied Energy Journal, Vol. 7, No. 4, Barking, Essex, U.K. December 1980, Applied Science Publishers, pp. 263-280.

[2] UNIDO, "World Industry in 1980, Vienna, 1981, United Nations, pp.182 and 184.