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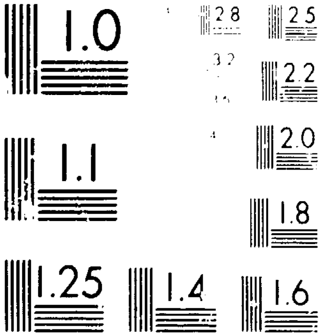
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United Nations Industrial Development Organization

Distr.
LIMITED

ID/WG.356/1
19 November 1981

ENGLISH
Original: FRENCH

Third Small Expert Group Meeting on Scenarios of the Iron and Steel Industry's Development

Vienna, Austria, 3-4 December 1981

1990 SCENARIOS FOR THE IRON AND STEEL INDUSTRY

"SPECIAL DOSSIER"

Complementary paper to DOSSIER III

"Markets, product ranges and scale economies"

STUDY OF MARKETS FOR THE IRON AND STEEL SECTOR CREATED BY THE DEVELOPMENT AND DIVERSIFICATION OF ENERGY PRODUCTION *

(Based on the IIASA energy model)

* This is a translation of a document which has not been formally edited.

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Annexes

I. INTRODUCTION

1. Background to the study

The energy crisis is at present the main concern of economists and politicians, probably because it questions many of the structures of industrialized societies, but also - and above all - because it has highlighted the interdependence between the industrialized and the developing countries. The energy question therefore affects the world order as a whole. We may also legitimately wonder if it is (or will be) possible to alleviate this crisis.

All hope is in fact not irrevocably lost, thanks to the possibility of a fresh start provided by the emergence of new sources of energy. But under what conditions the transition can be made, to what extent and for the benefit of whom are still very debatable questions.

Some of these new technologies disturb the existing energy production framework: some, such as nuclear production, because of a very high concentration of potential; others, such as solar energy or the biomass, because of their very specialized, even personalized production. It may then be wondered if the changes in or at least the diversification of sources of energy will not shatter the old industrial structures. Must we therefore be prepared for reconversions in industry? Or on the contrary, will these new technologies not bring renewed activity to industry?

Here we come to the question which is the subject of this study: can the development of new sources of energy have an influence on the demand for steels?

It is clear how diversified the reply to this question will be and how many parameters it must take into account. Although a global study can give an indication of trends, a true idea of the situation can be obtained only in so far as account is taken, on the one hand, of the differences between the technologies and, on the other, of their geographical and economic impact.

There is also a third point, related to these two approaches: the quality of the steels. Advanced technologies are more likely to demand special steels than traditional technologies. This again poses the question of the interaction between energy producers and industrialized countries. In other words: what will be the developing countries' share in the demand for energy, in relation to that of the industrialized countries in the production of steel (especially special steels)?

It is quite obvious that the limits of such a study will not permit consideration of problems of political economy; the essential object will be to determine the problems connected with the production of energy. from both the objective and scientific points of view, bearing in mind both the merits and the limitations of such an approach. It is clear, however, that a final assessment, especially at the world level, should take into account much more uncertain factors than those to be considered here.

2. Presentation of the question

The framework of this study therefore deals with only one aspect of the problem, which we shall now define.

The general question with which we are concerned is simple to formulate - "to study the influence of the development of new forms of energy on the demand for steel" - but much more complex in its implications. In fact, it involves not only making a global calculation of forecast demand for steel, but also defining the importance of each parameter involved. We must therefore begin by replying to a series of special questions, before producing a balanced reply in the form of a synthesized evaluation. The balance of this final reply obviously depends on the calculated results of each preliminary study. In order to balance this reply by dealing with each parameter, a small model has been developed for computerized treatment.

Before defining the method of work, however, let us try to define the questions to be tackled.

(a) Is there a foreseeable global evolution of world demand for steel aroused by the energy sector?

(b) What will be the share of the new energy production technologies in this evolution?

(c) What will be the geographical distribution of these technologies and their impact on the iron and steel industry?

(d) Is the evolution of energy production developing towards an ever-increasing demand for special steels?

These are the four preliminary questions which must be answered before deciding whether or not the demand for steel can be reactivated by world energy developments; they are therefore the four sections into which this study will be divided.

3. Bibliographic research

To obtain material for this study two kinds of bibliographical research were necessary:

A collation of objective data expressed in figures, to be used in preparing basic numerical calculations;

An analysis of works of synthesis and special studies done on the subject.

Although there are plenty of figures in the energy and industrial statistics of the various countries, as well as the studies undertaken by Governments, basic works on the subject have been found to be very rare.

In addition to the bibliography available at IIASA, the PASCAL data bank of CNRS, Paris, was also consulted. We were, however, able to obtain only one title: "Environmental Resource Assessment Programme, Department of Energy, pub. No. D.O.E./ET-0020/1" (2).

On the other hand, the bibliography consulted has always listed a profusion of studies and assessments concerning the influence of the energy crisis on iron and steel, or on the energy requirements of this industry.

All the literature available at the time of this study is listed in Annex 1. The discussion of individual publications will be found in the body of the study. The small number of works makes it unnecessary to undertake a critical confrontation of the different arguments.

The basis of the study is therefore the report by the Energy Systems Program Group of IIASA (Laxenburg, Austria) entitled: Energy in a Finite World: A Global Systems Analysis (2 volumes, 837 pages), Wolf Häfele, Programme Leader, Ballinger, 1981 (1)

It is in fact the only global study which can supply energy scenarios at present. The calculations are therefore based on the data given in these scenarios. The information the report contains can also be completed by the special study by Arnulf Gruebler (IIASA) on the energy chains approach (6).

For the data in figures both quantitative and qualitative, the basis is the data of the annual report prepared for the United States Department of Energy, published by Bechtel National Inc. (San Francisco) entitled: "Resource Requirements, Impacts and Potential Constraints Associated with Various Energy Futures", 1978 (3).

Specific data will be added for solar energy (7).

It will easily be understood that a hierarchy in the importance of these data becomes established by the very nature of their content, but that their quality irrespective of this hierarchy is not always equal. One example is the absence of tables setting out the global results approach in the IIASA study; or again certain percentage errors in the Bechtel report. A critical eye must therefore be kept on the data throughout this study.

4. Explanation of the method

As shown in the summary at the beginning of this report, the study itself is based on four chapters analysing the different parameters with a final chapter synthesizing them. The four analytical chapters are constructed as follows:

- A study at the world level of the demand for ferrous metals, directly based on the report of the IIASA Energy Systems Program Group (1). The aim of this study is not to set guidelines for the subsequent analyses but on the one hand to establish some basis for comparison between a broad assessment and the partial conclusions reached in a detailed study and, on the other hand, while serving as a starting point for critical reasoning, to highlight the crucial elements in the interaction between the evolution of energy production and the iron and steel industry.

- An analysis of the Bechtel data (3), including the justification of their use and their conversion to a standard unit usable in a more general comparative framework. Here this analysis plays the role of a data bank. On it will be based all subsequent calculations. It is in fact a matter of collating the figures, classified according to the type of technology and the quality of the steel used.

This analysis of data forms part of the pre-assessment work; just as the IIASA global scenarios (1) will define the operational structure of the evaluation, this analysis will provide the indispensable numerical elements.

- A comparative analysis of some simplified chains. With this chapter, we approach the structural study; in fact, it introduces the idea of secondary energy, i.e. it deals with what happens to crude ore from its extraction until its final consumption. This is called the "energy chain". Consideration of this factor makes it possible to correlate gross results, since we then take into account the productivity of conversion plants. This also introduces the by no means negligible factor of the transport of primary sources of energy and secondary converted sources, the former to the conversion plants and the latter to the final user.

- The analysis of simplified chains applied to the "high" IIASA scenario. This is as it were the crossroads of the preliminary analyses. It is in fact here that the main body of the evaluation is centred, on the structural basis of the IIASA scenarios, taking into account the idea of an energy chain and parameters taken from Bechtel (3): the types of steels, the types of technology.

This analysis enables a micro-model applicable to any scenario to be developed on these same bases. This should make it possible to vary the replies according to the scenario chosen, without forgetting, however, that whatever the scenario the reply obtained will be indicative only in the framework of the scenario and not "the" true one.

This analytical method has been applied to the example of the IIASA "high" - therefore optimistic - scenario, in order to base the assessment on a quantifiable scale of values.

A "regionalized" example applied to oil has also been included, providing an indication of the relations between consumers and producers of sources of energy and steel. The lack of usable data has restricted this factor to a single example.

The last chapter draws conclusions from this study as regards methodology, the over-all view and the regionalization of the problem. The principal lessons provided by this study will be given under the heading "Note".

The bibliography, the Bechtel data and those for solar energy and the development of the micro-model referred to above will be found annexed.

II. GLOBAL EVALUATION

5. The spirit of the IIASA study

The following principles underlie IIASA's approach to the energy question:

Generalized vision and analyses, i.e. not yielding to the constraints of short-term views, which are necessarily affected by a political context;

Systemized analytical methods;

Homogeneity in taking account of factors.

It should be borne in mind that IIASA's approach was intended to be objective, and consequently without any pragmatic consideration or political, economic or other competitive spirit.

It therefore adopts the geographical framework of the whole world and the time frame of the next 50 years.

The countries of the world are split up into seven regions according to the following criteria:

R.I: North America - rich in resources, developed market economies

R.II: USSR and Eastern Europe - rich in resources, developed centrally planned economies

R.III: Western Europe, Australia, Israel, Japan, New Zealand, South Africa - poorer in resources, developed market economies

R.IV: Latin America: rich in resources, developing market economies

R.V: South and South-East Asia, Central Africa - relatively few resources, generally market economies, developing

R.VI: Middle East and North Africa - rich in resources (oil, gas). economies in transition

R.VII: China and Asian countries with centrally planned economies, developing, modest resources.

Within these geographical and time frameworks, the IIASA study makes a special point of investigating a selection of constraints at the world level, along the following lines:

Relative development of regions;

Available resources (for the period under consideration) for the different forms of energy;

Global constraints (human or technological) relating to each main type of technology.

The results of these analyses will be taken into account as objective indices, which will serve as gross (and constant) calculation factors in order to make the final evaluations homogeneous and comparable.

6. The results published by IIASA

On the basis of the global study published by IIASA (1) the materials requirements have been evaluated for each of the energy strategies envisaged. These assessments of course take into account the regionalization described above and the demographic evolution related to it. The strategies described are also based on: on the one hand, a "high" scenario which considers that energy consumption will attain 35.7 TW-years/year in the year 2030, or approximately four times that of 1975 (8.2 TW-years/year); on the other hand, a "low" scenario, which is less optimistic and evaluates at some 22.4 TW-years/year the energy consumption in the year 2030.

These two scenarios make it possible to foresee two perspectives in the future, one relatively optimistic, the other less favourable. In no case does either claim to be any sort of a prophecy.

Thus, if the "high" scenario is taken as a basis, with the aim of contemplating a rather favourable future, the figures for the world demand for ferrous metals compared with those of world economic growth seem of little significance. Table 1 shows this comparison based on the estimates on pages 645 and 433 (1):

Table 1

Comparison of the growth rates of the demand for ferrous metals and of the world economy

Year	1975	1980	1985	1990	2000	2015	2030
Ferrous metals index - base 75	100	135		180	250	400	530
Growth of the demand for ferrous metals - % per year	5		2.5			3	2
World economic growth - % per year	4.7			3.8		3	2.7

7. Comments on these results

In the light of this table, two comments should be made:

First: It can be noted that in general the growth of the demand for ferrous metals is less than that of the world economy. In other words, even the "high" scenario does not appear at all optimistic about the development of the iron and steel industry - in general, that is. This would tend to show that even if the energy sector could have a stimulating effect on the iron and steel industry, that effect would not be significant at the world level.

Second: The world economic growth rate decreases regularly (4.7 per cent for 1975-1985, 2.7 per cent for 2015-2030), whereas that of the demand for ferrous metals is irregular, since it shows an increase for the period 2000-2015. We may justifiably assume that over this period some stimulating factor will make itself felt.

The result is that the growth of the demand for ferrous metals for energy requirements will remain lower over all than that of the world economy. Consequently, it does not seem that the global impact of energy production on the iron and steel sector should be significant before the period 2000-2015.

It remains to be considered not only on what factors this supposed "revival" for 2000-2015 depends, but also whether it will be confined to one specially fortunate sector or will extend to steel production as a whole. In other words, it is important to ask ourselves what production technologies will justify this revival - unless it is a mass factor parallel to demography - and what types of steels are required for each of them.

LYSIS OF BECHTEL DATA

: of the data

It should be remembered that here it is a question of setting up a kind of data bank which could be used in the framework of the analyses. These data must be both sufficiently diversified and reliable. Consequently it is necessary on the one hand to collect figures for each technology, on the other to find out to what extent they are representative at the world level. The data are drawn from "Resource Requirements, Impacts and Potential Constraints Associated with Various Futures" (3). We shall refer principally to appendix B to this report.

The main points are:

(a) As regards petroleum production:

1. Onshore extraction;
2. Offshore extraction;
3. Extraction in North Alaska;

(b) As regards gas production:

1. Conventional onshore extraction of natural gas;
2. Assisted onshore extraction;
3. Offshore extraction;

(c) As regards coal production:

1. Opencast mining (East);
2. Opencast mining (West);

(d) As regards coal gasification:

1. High BTU gasification;

(e) As regards the liquefaction of coal:

1. Heavy fuel liquefaction;

(f) As regards electricity production:

1. Oil-fired power-station: 800 MW(e);
2. LWR (1100 MW(e)) nuclear power-station;
3. Breeder reactor (1000 MW(e));
4. Hydroelectric project (200 MW(e));
5. Solar power-station (100 MW(e)).

These production references for primary and secondary sources of energy must be completed by data concerning their transport or distribution:

(a) As regards oil:

1. Traditional pipeline;
2. Pipeline for the transport of petrol from Alaska;

(b) As regards gas:

1. Gas pipeline;
2. Distribution plant;

(c) As regards electricity:

1. High-tension line : 230 kV alternating
2. 345
3. 500
4. 765
5. 400 kV direct
6. Overhead distribution line.

The data concerning a solar power-station with a capacity of 100 MW(e) planned for central Spain in the year 2010, the coefficients of which have been calculated from the information given by Mitre Corp. (7), will also be taken into account.

The tonnages of steel required for each of these categories are given under three headings:

Carbon steel;

Alloy steel;

Stainless steel.

These gross data will therefore be reduced to percentages; then their total will be compared with the production or transport potential, giving a ratio between a standard production and the corresponding demand for steel for each technology.

The characteristics of these plants, as well as the unprocessed data, will be found in annex 2.

9. Conversions to the standard unit: TW-years/year

In order to make the values of all these data homogeneous and comparable, they must be converted to a standard unit, valid for calculations all over the world, the terawatt-year per year (TW-year/year). We give below the conversion factors which have been used for the various units.

(a) Oil production or pipeline flow are given in (M)BpD ((millions of) barrels per day)

$$1 \text{ TW-year} = 5.2 \times 10^9 \text{ barrels}$$

$$\text{therefore } 1 \text{ TW-year/year} = \frac{X \times 365^*}{5.2 \times 10^9}$$

X given in barrels/day

(b) The production or flow of gas pipelines are given in M cu ft (millions of cubic feet)

$$1 \text{ TW-year} = 30 \times 10^{12} \text{ cu ft}$$

$$\text{therefore } 1 \text{ TW-year/year} = \frac{X \times 365^*}{30 \times 10^6}$$

X given in millions of cubic feet/day

(c) Coal production is given in Mt/year (millions of tonnes per year)

$$1 \text{ TW-year} = 1.1 \times 10^9 \text{ tonnes}$$

$$\text{therefore } 1 \text{ TW-year/year} = \frac{X}{1.1 \times 10^3}$$

X given in Mt/year

---

* Depends on the number of operative days per year.

Note: Sometimes, especially for steel demand, the reference is to ST (short ton)

1 ST	= 907.2 kg	
therefore 1 tonne	= X x 0.9072	X given in short tons

(d) Electricity production is given in MW(e)/year

1 TW-year	= 1×10^6 MW(e)	
therefore 1 TW-year/year	= $\frac{X \times A}{1 \times 10^6}$	X given in MW(e) A = availability of the plant

10. Tables of data

Table 2 A. Oil production

Units	Production TW-years/ year	Total steel/ production steel/TW- years/year	Total steel tonnes	% carbon steel	% alloy steel	% stain- less steel
1. Onshore	1.281×10^{-4}	67,064,012	8,590.9	91.77	8.09	0.14
2. Offshore	1.404×10^{-3}	33,384,053	46,871.211	93.50	6.34	0.16
3. North Alaska	1.263×10^{-2}	1,487,922.9	18,799.906	94.50	4.97	0.53

Table 2 B. Gas production

1. Conventional onshore	3.65×10^{-4}	41,998,134	15,329.319	92.41	7.46	0.13
2. Assisted onshore	2.533×10^{-3}	10,287,211	206,057.206	91.93	7.98	0.08
3. Offshore	3.042×10^{-3}	32,821,136	99,841.896	94.13	5.77	0.09
Units	Idem	Idem	Idem	Idem	Idem	Idem

Table 2 C. Coal production

1. Opencast East	3.636×10^{-3}	4,882,736.8	17,753.631	92.04	7.52	0.44
2. Opencast West	5.455×10^{-3}	1,509,926.5	8,236.649	93.53	6.02	0.46
Units	Idem	Idem	Idem	Idem	Idem	Idem

Table 2 DE. Gasification and liquefaction of coal

1. Gasification	2.750×10^{-3}	56,591,680	155,627.119	86.74	8.81	4.45
2. Liquefaction	1.505×10^{-3}	30,245,565	45,519.575	87.93	7.97	4.10
Units	Idem	Idem	Idem	Idem	Idem	Idem

Table 2 F. Electricity production

1. Oil-fired power-station	4.4×10^{-4}	56,390,516	24,811.827	92.37	5.56	2.07
2. LWR nuclear power-station	7.81×10^{-4}	63,682,766	49,736.240	87.41	8.89	3.70
3. Breeder reactor	7.10×10^{-4}	46,024,683	32,677.525	85.48	9.74	4.77
4. Hydro-electricity	1.12×10^{-4}	89,922,143	10,071.280	97.10	2.59	0.31
5. Solar	4.0×10^{-5}	1,675,000,000	67,000	90.00	9.00	1.00
Units	Idem	Idem	Idem	Idem	Idem	Idem

Table 3 A. Oil transport

1. Traditional crude oil	5.5385×10^{-2}	377,419.291	57,569.000	99.73	0.21	0.02
2. Alaska	0.13461538	430,595.360	654,132.913	99.39	0.55	0.06
Units	Transport TW-years/year	Total steel/transport tonnes steel/TW-years/year for 100 km	Total steel tonnes	% carbon steel	alloy steel	% stainless steel

Table 3 B. Gas transport

Pipeline	9.96×10^{-3}	2,419,757	58,179.643	99.83	0.15	0.02
Units	Idem	Idem	Idem	Idem	Idem	Idem

Table 3 F. Electricity transport

1. 230 kV ac.	1.625×10^{-4}	15,146,155	19,805	98.48	1.42	0.1
2. 345 kV ac.	3.9×10^{-4}	7,093,164	22,260.69	98.47	1.43	0.1
3. 500 kV ac.	7.8×10^{-4}	5,058,666	31,751.527	96.23	3.54	0.13
4. 765 kV ac.	1.625×10^{-3}	2,648,088.2	36,626.19	94.46	5.38	0.16
5. ± 400 kV dc.	9.75×10^{-4}	5,586,576	70,127.64	76.75	22.98	0.26
Units	Idem	Idem	Idem	Idem	Idem	Idem

11. Comments on these data

Some comments are called for with respect to these data.

(a) Table 2 A

With regard to the figures obtained for a plant producing 1.281×10^{-4} TW-years/year of crude oil onshore, it must be remembered that this refers to North American extraction cor[illegible]ons. These data are therefore not applicable to production p[illegible]s with easier conditions. In fact, it may be noted that onshore extraction requires nearly double the amount of steel needed by offshore extraction to produce an equivalent quantity. These data (table 2 A (1)) cannot be taken into account in a global study.

(b) Table 2 C

The justification for taking account of the extraction data for the East as compared with the West of the United States lies in the difference in the quality of the deposits. The recovery rate, i.e. the ratio of the volume required to the volume of dead ground cleared is much higher in the West than in the East, which means that with a smaller production the mines in the Eastern United States have a much greater demand for steel. It was therefore necessary to have data on optimum extraction conditions and on more difficult conditions.

(c) Table 2 DE

Although this does not appear explicitly in the table, the production rates of the liquefaction plants, and especially those of coal gasification described in Bechtel (3), pose a problem.

With regard to liquefaction, Bechtel's figures give a productivity of 50.20 per cent (R = 0.502) - since there are ore inputs of 3.00×10^{-3} TW-years/year for a production of: 1.505×10^{-3} TW-years/year.

The production rate is therefore low, but acceptable. On the other hand, for gasification, according to the figures published, the rate is exceptionally low and therefore unacceptable. For ore inputs of 8.25×10^{-3} TW-years/year, Bechtel's data indicate a production of 2.75×10^{-3} TW-years/year only. The productivity rate of this plant would then be 33 per cent (R = 0.33). Now the average rate for such a plant is at least 60 per cent and can even be as high as 78 per cent productivity.

It must therefore be admitted either that there is an error in these particular data, or that they have been established on the basis of obsolete technology.

(d) Table 2 F

If the data on electricity production described here (cf. annex 2) are compared with those published by Electricité de France, it may be noted that the figures given are roughly comparable. We shall therefore keep to those of Bechtel.

One comment is, however, necessary concerning the hydroelectric project installations. A typical dam can in fact not exist since the type of dam depends entirely on the site, so that the reservoir capacity and the head depend essentially on the site. And it is precisely the construction of the dam which needs most steel. This therefore is only an example which can be taken as an average.

Lastly, data concerning a solar power-station have been calculated from the information given by Mitre Corp. (7), and are to be treated as indicative.

The figures obtained cannot be considered sufficiently representative of a technology to be taken into account. However, they do indicate that a solar power-station (at the present state of technology) requires an excessive investment in steel in comparison with the other technologies under consideration.

(e) Table 3

With regard to transport, whether that of primary or secondary sources of energy, the unit chosen must be as suitable as possible if it cannot be ideal. We shall therefore adopt an average measurement of distance allowing for adjustments as necessary. We should emphasize that there is no proportional relationship possible between the quantity of energy transported and the length of the pipeline or electric cable. This choice is made on the basis of convenience. We shall therefore use tonnes of steel/TW-year/year for 100 km (t/TW-year/year/100 km).

In the rest of the study, we shall adopt the option of specially favouring those technologies with the most intensive demand for steel in order to make the estimate more radical in the initial stage, since the over-all results drawn directly from the IIASA scenarios are not decisive.

IV. COMPARATIVE ANALYSIS OF SOME SIMPLIFIED CHAINS

12. The notion of an energy chain

The principle of an energy chain is that of following a source of energy upstream from its production and, above all, downstream. In other words, it is a matter of linking primary and secondary and then final energy.

A given raw source can be used as primary energy or undergo conversion operations before being distributed as secondary or final energy. In addition to further processing installations, the chain should take into account the necessary transport and distribution. All these operations are subject to various constraints (cf. Gruebler (6)), which include in particular the demand for steel.

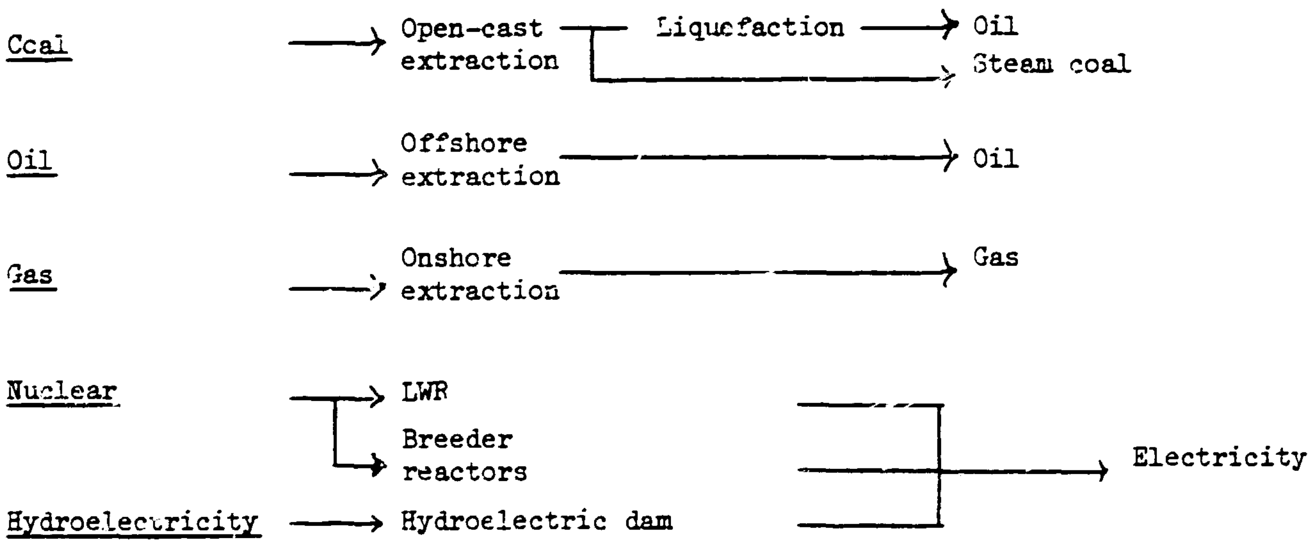
Let us take the example of coal:

1. The extraction requires mining installations
2. Once extracted, the coal may:
3 Be used as raw fuel ⟶ boilers
4. Be used in the production of energy ⟶ turbines
5. Be liquefied and (a) have to be transported by an oil pipeline
   (b) be used as fuel oil (cf. fuel oil)
6. Be gasified and (a) have to be transported by gas pipeline
   (b) be used as gas (cf. gas).

It may be noted that there are intersections between the different primary chains (liquefied coal ⟶ fuel

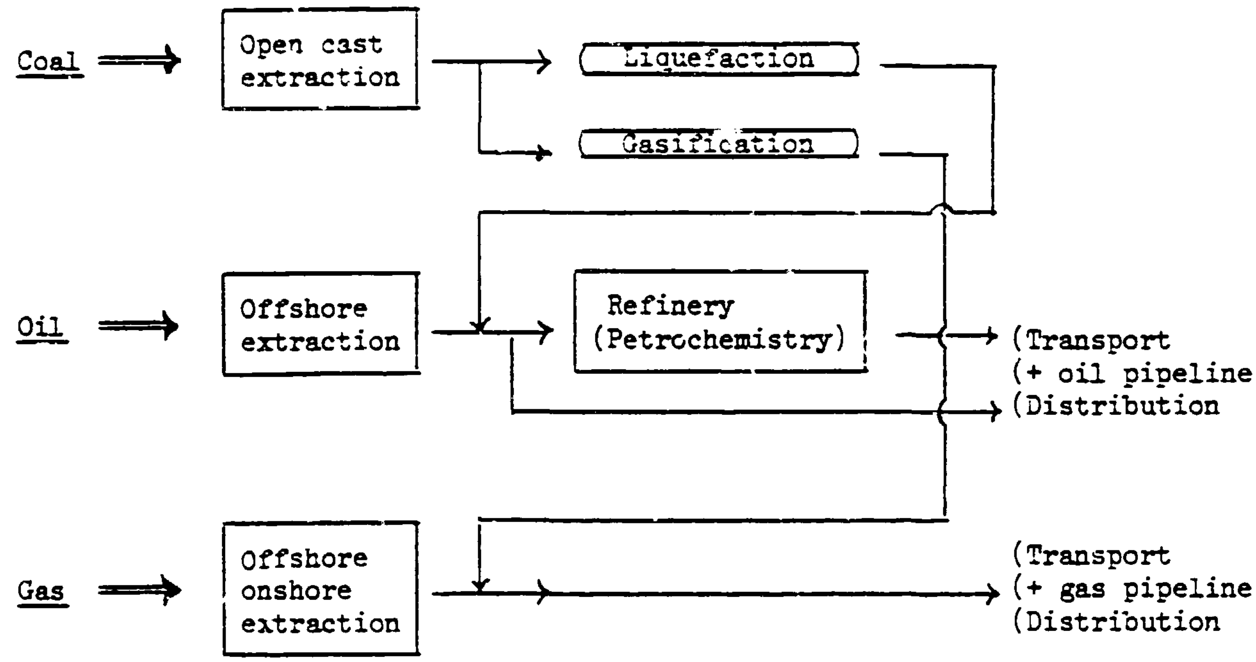
gasified coal ⟶ natural gas).

In the rest of the study we have retained only a few important intersections, describing the following skeleton chains:

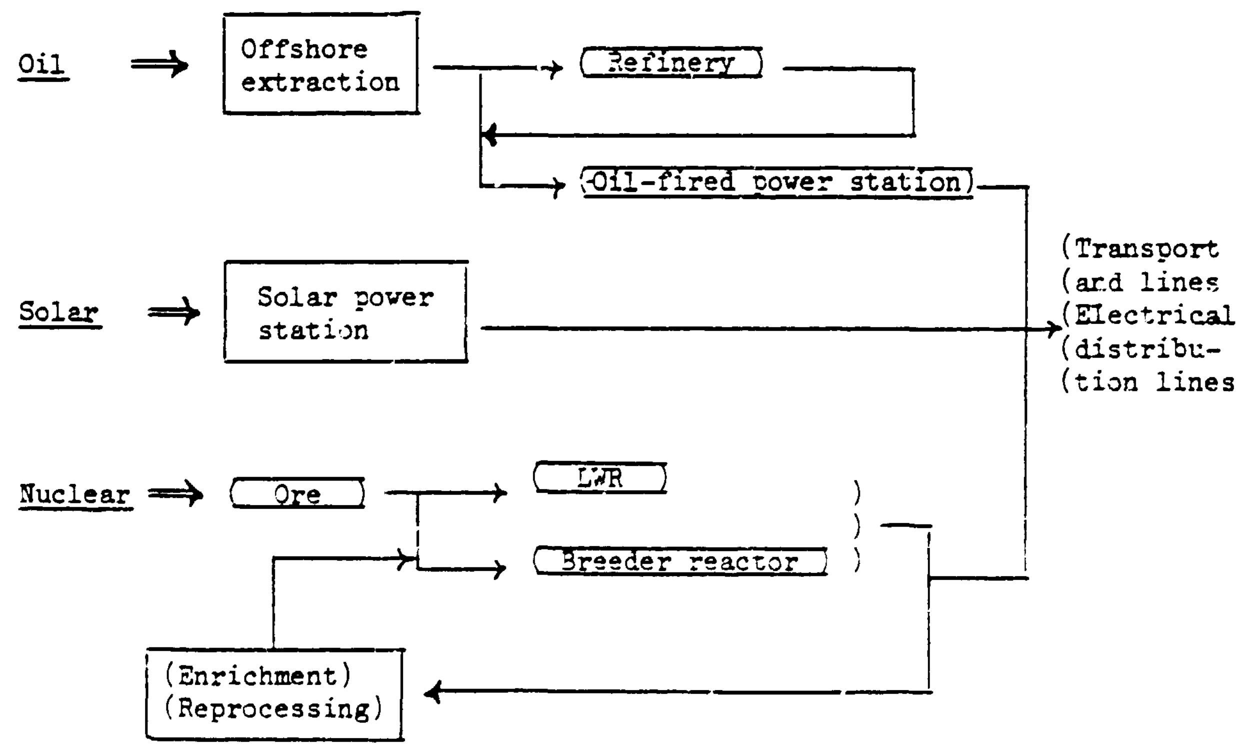


Hydroelectric power cannot be taken into account for the reasons given above (cf. section 11.d.): the scale factor and the specific characteristics of the site.

13. Chains for petroleum and synthetic petroleum by liquefaction of coal, gas and synthetic gas from coal



14. Electricity chains: nuclear - oil fuel - solar



V. ANALYSIS OF THE SIMPLIFIED CHAINS AS APPLIED TO THE "HIGH" IIASA SCENARIO

15. Reminder concerning the scenario

The IIASA scenarios (1) give values in figures at the world level only. Although calculations were made for each of the seven regions of the world (cf. section 5) through an energy demand model, no data for any individual technology have been prepared from the regional point of view. What can be deduced from it is therefore too imprecise to answer our question directly.

Consequently, the work still remains to be done, since no equivalent study exists - apart from that by Arnulf Gruebler (6), which deals only with a very minor aspect of the problem. The global primary energy supply in TW-years/year, according to tables 17-2 on pages 522 and 523 of volume 2 and 8-10 on page 145 of volume 1, is shown in the following table:

Table 4

World demand for primary energy: TW-years/year

	1975	2000	2030
Oil	3.83	5.89	6.83
Gas	1.51	3.11	5.97
Coal	2.26	4.94	4.98
Liquefied coal	0.00	0.00	*7.13
LWR	0.12	1.70	3.21
Breeder reactor	0.00	0.04	4.88
Hydroelectric power	0.50	0.83	1.46
Solar	0.00	0.10	0.49
Other	0.00	0.22	0.81
Total	8.21	16.84	35.65

The IIASA "high" scenario therefore covers two periods:

1975-2000: The structure of the primary energy supply remains mainly comparable with that of the present day, apart from LWR.

With regard to new technologies, solar energy does not begin until 2000; the same applies to the liquefaction of coal, which is in its very early stages, and breeder reactors.

Gas however will double between 1975 and 2000.

Oil remains the priority fuel over this period.

2000-2030: Changes will be introduced at the technology level with:

The introduction of breeder reactors; an increase in the role of electricity;

The liquefaction of coal; diversification of liquid fuel sources;

The emergence of solar energy on a commercial scale;

The emergence of other renewable sources of energy, such as biomass.

16. Raw processing of the data: global case

A diversified study by technology must therefore be made in order to arrive at a more precise estimate of the demand for steel. It would also be desirable to undertake a sensitivity analysis adapted to each region.

On the basis of the data collected and discussed in chapter III and the indices for growth and useful life of each technology published by IIASA, a first set of calculations has been established concerning primary energies. The calculation principle is as follows: one applies to the typical demand for steel by technology the investment coefficient established by five-year period on the basis of IIASA growth indices.

Calculation of growth rates by five-year period:

$$M(t) = M(t-1) + 5\Delta$$

where $M(t)$ = production at time t by technology

t = year (from five to five)

Δ = growth in TW-years/year.

Calculation of gross investment by technology and by five-year periods:

$$SM\ (t) = 5\,\Delta + \frac{5\ M(t-1)}{T} + \frac{10\,\Delta}{T} = 5\left[\frac{M\ (t-1)}{T} + \Delta\,(1 + \frac{2}{T})\right]$$

where T = useful life of the technology (average estimate).

The calculations concerning M (t) and δM (t) by technology, as well as Δ and T, will be found in annex 3.

The demand must then be calculated according to the types of steel, in order to measure their importance concurrently with the development of individual technologies. For this purpose, the percentage coefficient obtained from the Bechtel data (cf. section 10) will be applied to the total result; this will give a distribution of the evolution of the demand according to the type of technology and the type of steel.

A first set of results applied to primary energies will then be obtained: see table 5 below.

17. Discussion of demands for steel

From this first unprocessed set of data, the yearly growth rate of demand for steel due to the evolution of the energy sector can be calculated for each period, as well as the share of each technology in the demand.

Table 5

Evolution of world demand for steel for primary energies: oil, gas, coal, hydroelectricity, nuclear

in thousands of tonnes/year (average over 5 years)

	Year:	1980	1985	1990	1995	2000	2005	2010	2015	2020	2025	2030
Total	Carbon steel	22710	24895	27082	29266	31453	46281	50402	54522	58642	62762	66883
	Alloy steel	1668	1840	2012	2184	2356	3802	4178	4553	4929	5304	5679
	Stainless steel	202	230	257	285	312	977	1111	1246	1380	1515	1649
	Total steels	24580	26965	29351	31735	34122	51060	55691	60321	64951	69581	74211
Oil	Carbon steel	10885	11742	12600	13457	14314	13386	13712	14038	14363	14689	15016
	Alloy steel	738	796	854	912	970	908	930	952	974	996	1018
Offshore production	Stainless steel	19	20	21	23	24	23	23	24	25	25	26
	Total steels	11642	12558	13475	14392	15308	14317	14665	15014	15362	15710	16060
Gas	Carbon steel	5662	6283	6904	7525	8146	10105	11030	11954	12880	13805	14729
	Alloy steel	457	507	557	607	658	816	890	965	1040	1114	1189
	Stainless steel	8	9	10	11	11	14	15	17	18	19	21
	Total steels	6127	6799	7471	8143	8815	10935	11935	12936	13938	14938	15939
Coal Open-cast mine, West USA type	Carbon steel	268	293	318	344	369	586	641	697	752	807	862
	Alloy steel	17	19	20	22	24	38	41	45	48	52	55
	Stainless steel	1	1	2	2	2	3	3	3	4	4	4
	Total steels	286	313	340	368	395	627	685	745	804	863	921
Liquefaction of coal	Carbon steel	0	0	0	0	0	6137	7274	8410	9546	10683	11820
	Alloy steel	0	0	0	0	0	556	659	762	865	966	1071
	Stainless steel	0	0	0	0	0	286	339	392	445	498	551
	Total steels	0	0	0	0	0	6979	8272	9564	10856	12149	13442
Nuclear LWR	Carbon steel	3976	4561	5148	5735	6320	6143	6610	7076	7544	8010	8478
	Alloy steel	404	464	523	583	643	625	672	720	767	815	862
(pressurized water)	Stainless steel	168	193	218	243	268	260	280	300	319	339	359
	Total steels	4548	5218	5889	6561	7231	7028	7562	8096	8630	9164	9699
Nuclear breeder reactors	Carbon steel	0	0	0	0	0	6823	7880	8938	9996	11054	12112
	Alloy steel	0	0	0	0	0	777	898	1018	1139	1260	1380
	Stainless steel	0	0	0	0	0	381	440	499	558	617	676
	Total steels	0	0	0	0	0	7981	9218	10455	11693	12931	14168
Hydro-electricity a/	Carbon steel	1919	2015	2111	2205	2303	3101	3255	3409	3561	3713	3866
	Alloy steel	51	54	56	59	61	83	87	91	95	99	103
	Stainless steel	6	6	7	7	7	10	10	11	11	12	12
	Total steels	1976	2075	2174	2271	2371	3194	3352	3510	3667	3824	3981

a/ Corresponds to the Bechtel data base. Is to be taken as an indication. A sensitivity analysis should be done on these coefficients in order to improve the result, especially for the developing countries.

Table 6

Growth rate of steel demand by period

percentage/year

Period	1980-2000	2000-2015	2015-2030
Growth of world steel demand	1.65	3.87	1.39
Growth of demand for special steels (alloy + stainless)	1.79	5.31	1.57

Table 7

Share of each technology in the world demand for steel in percentages

Year	1980	2000	2005	2015	2030
Oil	47.3	44.8	28.0	24.9	21.6
Gas	25.0	25.8	21.0	21.4	21.5
LWR	18.5	21.2	13.0	13.4	13.1
Hydroelectricity	8.0	7.0	6.3	5.8	5.4
Coal	1.2	1.2	1.2	1.2	1.2
Breeder reactor	0	0	15.6	17.3	19.1
Liquefaction	0	0	13.7	15.9	18.1

The choice of years for establishing this table was based on the results set out in table 6, which show clearly that there will be an acceleration of growth during the period 2000-2015, due above all to the emergence of technologies with a large demand for special steels. The proportion of special steels, due in fact to the development of advanced technology energies (breeder reactors, up to 19 per cent in 2030), increases by 275 per cent over the whole of this period: 0.8 per cent in 1980; 2.2 per cent in 2030.

This first global estimate on the basis of IIASA's "high" scenario brings out several points:

The confirmed importance of oil up to the end of the period;

The constant importance of the share of gas (25 per cent in 1980 - 21 per cent in 2030);

The acceleration of the growth of demand for steel between 2000 and 2015;

The role played by the emergence on a commercial scale of advanced technology energies - breeder reactors, coal liquefaction, solar - during the first years of the century.

This assessment, however, cannot be final, because it does not take into account the distribution factor steel demand/production. That is the whole problem of a study by regions:

1. What regions demand special steels?
   Do they produce them?

2. Will the development of oil or coal in developing regions rich in resources not be accompanied by simultaneous acceleration of the growth of the local iron and steel industry?
   Or will it favour the developed countries which are poor in resources?

18. <u>Regionalization of the discussion</u>

Regionalization seems to be a decisive element in assessing the impact of energy evolution on the demand for steel. One study per region, however, comparable to the preceding general study (cf. sections 16-17) needs regional data; the IIASA report (1) gives them only in the form of relatively imprecise diagrams. Consequently, an accurate estimate cannot be produced on the basis of the IIASA scenarios, which is regrettable.

In order to reply to the questions raised above (cf. section 17) concerning whether or not certain regions have the capacity to produce the steel necessary for their energy requirements, it would be desirable to have access to such data.

It would in fact be interesting to look at the UNIDO steel scenarios (8) from the point of view of the IIASA energy scenarios (1) or, more generally, from the point of view of any energy study. Discussion by region of synthesized studies concerning all the technologies of the region would provide a more dynamic view of the evolution of the demand for steel.

The study at the world level shows that there will be a period of accelerated growth between 2000 and 2015, but on a global average. It is obvious that this growth in the demand for steel will not affect all regions to the same extent. It is very probable that the customers for increasing amounts of carbon steel will not be the same as those for special steels, because of the difference in the technological level. It would be important to know, for example, whether new regions producing petroleum offshore are not also capable of developing a self-sufficient iron and steel industry (Latin America). It is just as important to know whether advanced technology energies can be developed in developing regions which would not have sufficient means to produce special steels,* concurrently with industrially developed regions (regions I and III).

It has been feasible to undertake this study by regions for only one strategy: oil production offshore and by liquefaction of coal. It must be possible to generalize it, not only for all energy strategies but also for all strategies within each region.

19. <u>The case of oil: an example of a regional study</u>

The "oil" strategy includes four items of data per region:

The demand for oil;

The production of crude oil;

The production of synthetic oil by liquefaction of coal;

The transport and distribution requirements.

Only the first three are taken into account in the following results, the problems of transport and distribution being left open. Moreover, for the reasons set forth in section 11 (a), the production of crude oil is calculated on the basis of offshore extraction only.

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* (Regions V and VII).

In the case of region III and region V, which are importers of crude oil, one traditionally, the other as from 2000-2005 (if we use the IIASA data), a sensitivity analysis must be made. The study of the demand for steel must be based on the demand for energy and not on production. In this case, global demand has been transferred to petroleum.

For region III the hypothesis has been adopted that the region should itself supply all the equipment necessary to the production of the oil it imports.

For region V, the aim is to assess the demand for steel corresponding to the total demand for oil, in order to define the gaps in steel production that the region can or cannot fill. Moreover, for Africa, where recent prospecting has led to the discovery of off-shore reserves, the IIASA figures may be considered somewhat low.

Table 8

Evolution of demand for steel related to IIASA oil strategies by region in millions of tonnes per year

Region		Year:	1980	1985	1990	1995	2000	2005	2010	2015	2020	2025	2030
I	Oil (offshore production)	Carbon steel	1523	1482	2713	2905	3196	2426	1415	2730	2189	874	1448
		Alloy steel	103	100	184	197	217	164	96	185	148	59	98
		Stainless steel	3	3	5	5	5	4	2	5	4	1	2
		Total	1629	1585	2902	3107	3418	2594	1513	2920	2341	934	1548
	Liquefaction of coal	Carbon steel	0	0	0	0	345	581	1596	655	1042	2183	1791
		Alloy steel	0	0	0	0	31	53	145	59	94	198	162
		Stainless steel	0	0	0	0	16	27	74	30	49	102	83
		Total	0	0	0	0	392	661	1815	744	1185	2483	2036
II	Oil (offshore production)	Carbon steel	1806	1669	1731	1794	1856	1848	1677	1020	1519	1519	1519
		Alloy steel	122	113	117	122	126	125	114	69	103	103	103
		Stainless steel	3	3	3	3	3	3	3	2	3	3	3
		Total	1931	1785	1851	1919	1985	1976	1794	1090	1625	1625	1625
	Liquefaction of coal	Carbon steel	0	0	0	0	0	115	423	1244	998	1183	1321
		Alloy steel	0	0	0	0	0	10	38	113	90	107	120
		Stainless steel	0	0	0	0	0	5	20	58	46	55	62
		Total	0	0	0	0	0	130	481	1415	1134	1345	1503
III	Oil (offshore production)	Carbon steel	2693	1390	899	787	583	543	537	545	291	541	1036
		Alloy steel	183	94	61	53	40	37	36	37	19.5	37	70
		Stainless steel	5	2	2	1	1	1	1	1	.5	1	2
		Total	2881	1486	962	841	624	587	574	583	311	579	1108
	Liquefaction of coal	Carbon steel	0	0	0	0	0	517	957	2151	2387	1798	2417
		Alloy steel	0	0	0	0	0	47	87	195	216	163	219
		Stainless steel	0	0	0	0	0	24	45	100	111	84	113
		Total	0	0	0	0	0	588	1089	2446	2714	2045	2749

(continued)

Table 8 (continued)

Region		Year:	1980	1985	1990	1995	2000	2005	2010	2015	2020	2025	2030
IV	Oil (offshore production)	Carbon steel	941	1357	1382	1648	2310	2551	2984	3175	4174	4391	4878
		Alloy steel	64	92	94	112	157	173	202	215	283	298	331
		Stainless steel	2	2	2	3	4	4	5	5	7	7	8
		Total	1007	1451	1478	1763	2471	2728	3191	3396	4464	4696	5217
	Liquefaction of coal	Carbon steel	0	0	0	0	0	0	0	0	0	0	0
		Alloy steel	0	0	0	0	0	0	0	0	0	0	0
		Stainless steel	0	0	0	0	0	0	0	0	0	0	0
		Total	0	0	0	0	0	0	0	0	0	0	0
V	Oil (offshore production)	Carbon steel	1086	1040	1003	1066	1269	595	187	616	1090	1498	2555
		Alloy steel	74	71	68	72	86	40	13	42	74	102	173
		Stainless steel	2	2	2	2	2	1	0	1	2	3	4
		Total	1662	1113	1073	1140	1357	636	200	659	1166	1603	2332
	Liquefaction of coal	Carbon steel	0	0	0	0	0	0	287	340	279	311	170
		Alloy steel	0	0	0	0	0	0	26	31	25	28	15
		Stainless steel	0	0	0	0	0	0	13	16	13	14	8
		Total	0	0	0	0	0	0	326	387	317	353	193
VI	Oil (offshore production)	Carbon steel	1527	3575	3825	4357	4619	5710	6251	5094	4994	4994	5206
		Alloy steel	103	242	259	295	313	387	424	345	339	339	353
		Stainless steel	3	6	6	7	8	10	11	9	9	9	9
		Total	1633	3823	4090	4659	4941	6107	6686	5448	5342	5342	5568
	Liquefaction of coal	Carbon steel	0	0	0	0	0	0	0	0	0	0	0
		Alloy steel	0	0	0	0	0	0	0	0	0	0	0
		Stainless steel	0	0	0	0	0	0	0	0	0	0	0
		Total	0	0	0	0	0	0	0	0	0	0	0

(continued)

Table 8 (continued)

	Year:	1980	1985	1990	1995	2000	2005	2010	2015	2020	2025	2030
Oil (offshore production)	Carbon steel	732	970	1086	1323	1440	1677	1794	1748	932	341	- 2002 -
	Alloy steel	50	66	74	90	98	114	122	118	63	23	- 136 -
	Stainless steel	1	2	2	2	2	3	3	3	2	1	- 3 -
	Total	783	1038	1162	1415	1540	1794	1918	1869	997	365	- 2141 -
Liquefaction of coal	Carbon steel	0	0	0	0	0	0	345	523	1413	1991	3898
	Alloy steel	0	0	0	0	0	0	31	47	128	180	353
	Stainless steel	0	0	0	0	0	0	16	24	66	93	182
	Total	0	0	0	0	0	0	392	594	1007	2265	4433

Notes: 1. These demands for steel correspond to the application of the micro-model in annex 3 to the IIASA scenarios, as presented in the IIASA study (1).

2. Negative figures appear for the demand for steel caused by oil production in region VII. This is abnormal and proves that the decrease in oil production between 2025 and 2030 is too rapid and corresponds to a disinvestment.

Table 9

Evolution of the demand for steel corresponding to an oil production (by offshore oil technology) equal to the demand of importing regions III and V

	Year:	1980	1985	1990	1995	2000	2005	2010	2015	2020	2025	2030
Oil production corresponding to the demand of region III	Carbon steel	3325	3471	3829	3825	4112	4511	4407	4765	4761	4765	5011
	Alloy steel	225	235	260	259	279	306	299	323	323	323	310
	Stainless steel	6	6	7	7	7	8	8	8	8	8	8
	Total	3556	3712	4095	4091	4398	4825	4714	5096	5092	5096	5359
Oil production corresponding to the demand of region V	Carbon steel	608	1024	978	1365	1977	2006	2801	2984	3529	3925	4532
	Alloy steel	41	69	66	93	134	136	190	202	239	266	307
	Stainless steel	1	2	2	2	3	3	5	5	6	7	8
	Total	650	1095	1046	1460	2114	2145	2996	3191	3774	4197	4847

Notes:

1. For region III, the demand for steel corresponding to the production of the demand for petroleum is always higher than the demand for steel corresponding to domestic production of petroleum and synthetic petroleum combined. Petroleum imports make up the difference.

2. The same is not true of region V because it is an oil importer only after the year 2000.

VI. GENERAL CONCLUSIONS

20. Bibliographical analysis

Since the literature does not approach the question from the point of view of a possible reactivation of the iron and steel industry by the agency of the energy sector, the bibliographical analysis could relate only to general studies on energy.

It has been concentrated mainly on a methodical consideration of the report of the IIASA Energy System's Program Group (1).

As a complementary study, Arnulf Gruebler's analysis (6) on the comparison of energy chains has provided structural elements, but has not furnished any decisive data on the question of the transport of liquid fuels.

Throughout the study, both the virtues and deficiencies of the IIASA report have been noted, in particular on the one hand the effort to be exhaustive and on the other the absence of tables with figures by region indicating the approach to the global results.

As to the other titles in the bibliography, both Bechtel (3) and Mitre (7) are concerned with the search for raw data which is both sufficiently precise and diversified.

In this connection, it will be noted that these data are generally in line with the sources of the IIASA study. The only exceptions are the figures for onshore oil extraction and the limited nature of the solar data.

The contents of Environmental Resource Assessment Programme (2) have not been analysed, because it was impossible to obtain this work in time.

The other titles (4) (5) (8) are only given for reference.

It can be seen that the bibliography used is somewhat scanty, and there are probably other titles that would be useful for this study which do not appear in the indexes consulted.

21. Problems connected with the study

We must now sum up the problems connected with such a study:

The dearth of reference books available has just been emphasized.

The number of parameters means that the data are scattered and that it is not always easy to establish how they correspond.

The only usable energy scenarios are those of IIASA; they must be accepted as a basis but is must be remembered that the results obtained correspond to these scenarios. The existence and availability of other scenarios would make it possible to collate the estimates and provide elements of comparison.

The question of the transport and distribution of fluid fuels (oil, gas) is still approached in too restricted a manner to be integrated in the series of technologies forming the energy chains. Only unprocessed data per country are available; the extrapolation of these data at the level of a specific region of the world brings in a scale factor which has not yet been defined. Consequently, the estimates according to energy chains are incomplete.

Finally, the regionalization of the estimates, which is indispensable, requires homogeneous, complete data for all the regions. The absence of such data has hampered the work which should lead, through the development of the micro-model (cf. annex 3), to a synthesized regional assessment.

22. The global view

The results all show that up to the year 2000 oil is dominant. It would, however, be interesting to study whether, in addition to oil, certain new technologies, such as solar energy for example, have not a part to play. Such possibilities are not contemplated by the IIASA scenarios, in which oil and gas cover 70 per cent of the demand for steel caused by the energy sector.

Moreover, if we refer to the forecasts by Robert U. Ayres, quoted in (8), page 21, concerning the primary consumption of iron and steel, up to the year 2000 the ratio between the quantities of steel required in the IIASA global scenario, expressed in yearly terms, and the total yearly average primary consumption of iron and steel in the world remain constant at about 3.7 per cent.

After 2000 the emergence of nuclear energy and synthetic petroleum leads to an acceleration in the increase of the world demand for steel, and in particular special steels, but the increase becomes less again from 2015.

23. The "regionalized" problem

If the study regionalized according to the IIASA scenario (1) is related to the UNIDO iron and steel scenario (3), pages 58-59, it shows that the proportion of the demand for steel brought about by the development of the energy sector, for 1990, where oil remains dominant,

Is relatively small (about 2 per cent of production capacity) in Africa and Latin America (region V and region IV),

But on the other hand is substantial in the Middle East (region VI) (some 20 per cent of production capacity).

This is based on the IIASA hypotheses in which the demand for oil in region III was satisfied exclusively by region VI (Middle East - North Africa). These hypotheses should be diversified if we want to reach convincing regional conclusions.

24. Note

The study has made possible the critical establishment of a data base which can now be exploited by computer.

The IIASA energy scenarios have enabled the method to be tested. However, certain points remain pending.

1. Estimating the size of the distribution and transport networks for gas, electricity and petroleum remains a problem which, in the light of the data collected, may be of considerable weight in the demand for steel, especially for Latin America.

2. The IIASA scenarios have turned out to be difficult to handle because of the poor quality of the regional data. It also appears important to be able to modify the hypotheses and verify their economic coherence in relation to the scenarios developed by UNIDO (8).

The preparation of a set of energy scenarios which fit in with the hypotheses of the UNIDO scenarios and take into account contrasted hypotheses would seem to be the next stage in regionalizing the discussion. The preparation of the data base and its computerized handling through the micro-model are a good starting point in this direction.

Annex 1

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Annex 2

	Plant	Description
E1.	Onshore extraction of crude petroleum PETROLEUM	365 operating days/year. Useful life: 20 years. Production: 1,825 barrels per day.
E4.	Offshore extraction PETROLEUM	365 operating days/year. Useful life: 20 years. Production: 20,000 barrels per day.
E5.	Extraction in North Alaska PETROLEUM	365 operating days/year. Useful life: 20 years. Production: 180,000 barrels per day.
E19.	Conventional onshore extraction GAS	365 operating days/year. Useful life: 20 years. Production: 30 million cubic feet/day.
E20.	Assisted onshore extraction GAS	365 operating days/year. Useful life: 25 years. Production: 208.2 million cubic feet/day.
E21.	Offshore extraction GAS	365 operating days/year. Useful life: 20 years. Production: 250 million cubic feet/day.
E28.	Open-cast mine East United States COAL	253 operating days/year. Useful life: 30 years. Production: 4 million tonnes/day.
E29.	Open-cast mine West United States COAL	253 operating days/year. Useful life: 30 years. Production: 6 million tonnes/day.
E31.	Gasification of coal. GAS High BTU	330 operating days/year. Useful life: 25 years. Entry of ore: 27,500 tonnes of lignite/day. Production: 250 million cubic feet.
E34.	Liquefaction of coal Heavy FUEL OIL	330 operating days/year. Useful life: 25 years Entry of ore: 10,000 tonnes/day. Production: 23,710 barrels/day.
E51.	Oil-fired power-station ELECTRICITY	365 operating days/year. Useful life: 30 years. Capacity: 800 megawatts. Production: 3,854 million kWh/year. Availability: 55%.
E64.	LWR nuclear power-station ELECTRICITY	365 operating days/year. Useful life: 30 years. Capacity: 1,100 megawatts. Production: 6,842 million kWh/year. Availability: 71%.

Annex 2 (continued)

Plant	Description
E66. Breeder reactor ELECTRICITY	365 operating days/year. Useful life: 30 years. Capacity: 1,000 megawatts. Production: 6,220 million kWh/year. Availability: 71%
E67. Hydroelectric dam ELECTRICITY	365 operating days/year. Useful life: 60 years. Capacity: 200 megawatts. Production: 981 million kWh/year. Availability: 56%
T1. Transport by crude oil pipeline	360 operating days/year. Useful life: 40 years. Length: 150 miles. Diameter: 36 inches. Transport: 800,000 barrels/day
T2. Transport of oil from Alaska by pipeline	350 operating days/year. Useful life: 40 years. Length: 800 miles. Diameter 48 inches. Transport: 2 million barrels/day.
T17. Transport of gas by pipeline	360 operating days/year. Useful life: 40 years. Length: 150 miles. Diameter: 36 inches. Transport: 830 million cubic feet/day.
T18. Gas distribution plant	365 operating days/year. Useful life: 40 years. Flow: 50 million cubic feet/day.
T21. HT line, 230 kV, alternating	365 operating days/year. Useful life: 50 years. Length: 500 miles. Capacity: 250 megawatts.
T22. HT line, 345 kV, alternating	365 operating days/year. Useful life: 50 years. Length: 500 miles. Capacity: 600 megawatts.
T23. HT line, 500 kV, alternating	365 operating days/year. Useful life: 50 years. Length: 500 miles. Capacity: 1,200 megawatts.
T24. HT line, 765 kV, alternating	365 operating days/year. Useful life: [illegible] years. Length: 500 miles. Capacity: 2,500 megawatts

Annex 2 (continued)

Plant	Description
T25. HT line, ± 400 kV, direct	365 operating days/year. Useful life: 50 years. Length: 800 miles. Capacity: 1,500 megawatts.
T26. Overhead electric distribution line	365 operating days/year. Useful life: 50 years. Total capacity: 131.6 megawatts.

Annex 3

Micro-model

Aim of the model

Given

(1) A net energy strategy by five-year period (or level of production by line)

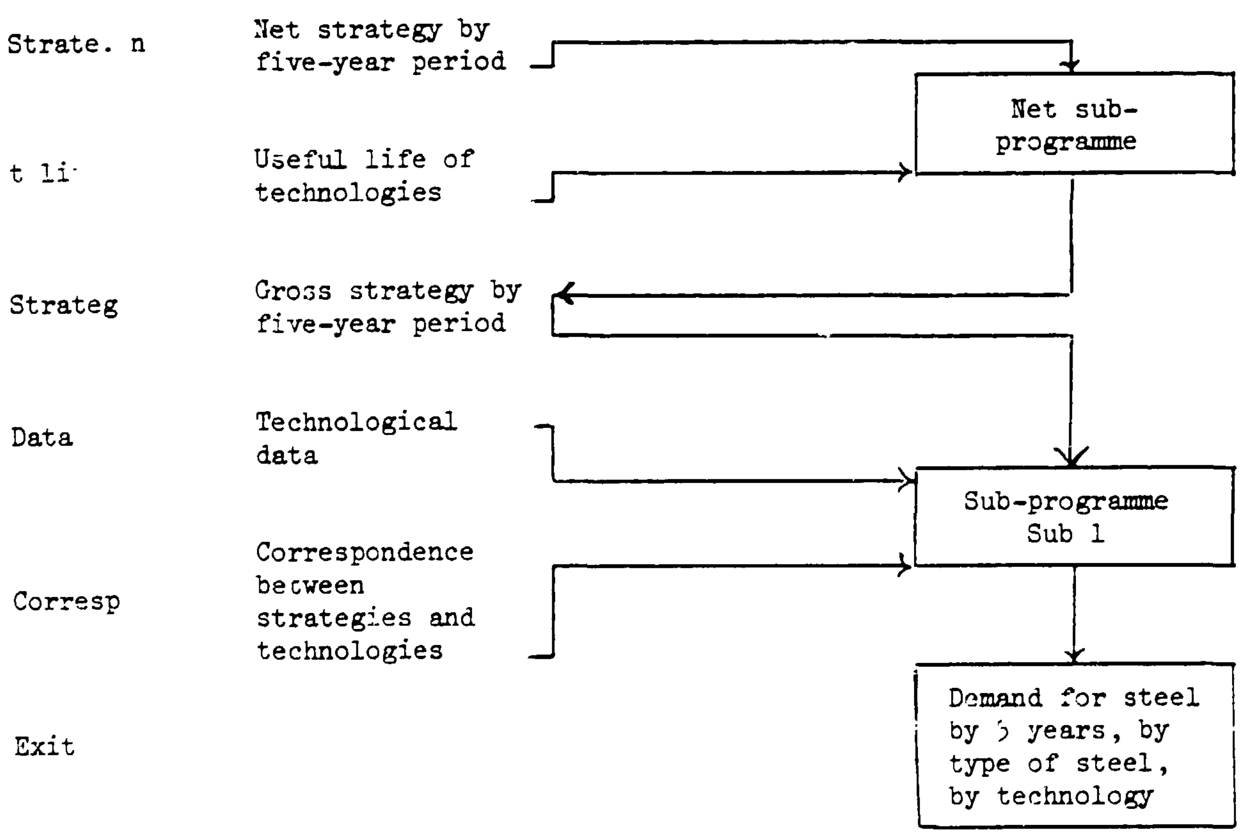
or a gross energy strategy, increase in capacity - including the investment to maintain the stock level (physical depreciation linked to the average useful life of the equipment) by five-year period;

(2) Technological data (cf. para. 3)

calculate the demand for steel in tonnes by five-year period, by type of steel (carbon, alloy, stainless) and by type of technology.

Data flow chart

Titles of corresponding files



Annex 3 (continued)

Comments

(1) The main programme only manages the sub-programmes and files.

(2) The "net" sub-programme is optional and is provided by the main programme if the answer to the question is "1". If the answer is "0", only sub-programme sub 1 is called on, taking the gross strategy directly from the "strateg" file, the last line of which should be void if not all the technologies of the "data" file are used.

(3) The "corresp" file establishes the correspondence between strategies and technologies. For example: strategy 1 is applied to technology 2 by having 1 in second place in "corresp".

(4) The conversion of a net strategy to a gross strategy operated by the "net" sub-programme corresponds to the following formulae:

If

$M_1(t)$	is the level of strategy 1 (production at instant t)
and $\Delta_1(t)$	is the increase in annual capacity
t life (1)	is the useful life of equipment 1 used by strategy 1

then for five years we have:

$$M_1(t+1) = M_1(t) + 5\Delta_1(t) \qquad (1)$$

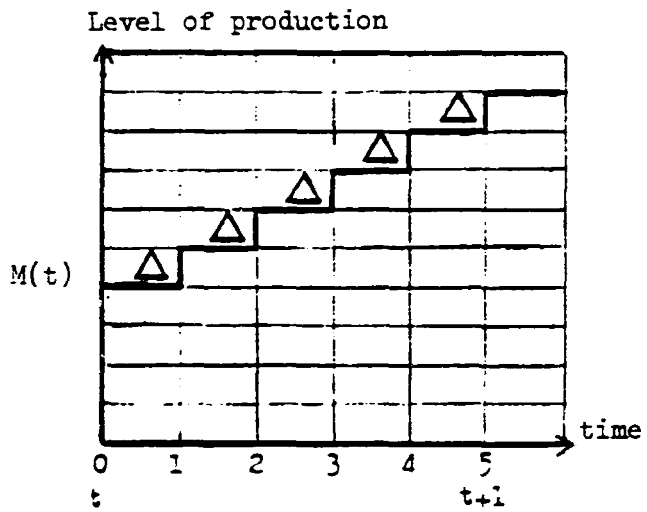
The gross investment over these five years is:

$$SM_1(t) = 5\Delta_1(t) + \text{amortization}$$

Annex 3 (continued)

Diagram

M(t + 1)



The amortization over these five years for the technology used in strategy 1 is:

$$\text{Amortization } 1 = \frac{5M_1(t)}{t \text{ life } (1)} + \frac{4\Delta_1(t)}{t \text{ life } (1)} + \frac{3\Delta_1(t)}{t \text{ life } (1)} + \frac{2\Delta_1(t)}{t \text{ life } (1)} + \frac{\Delta_1(t)}{t \text{ life } (t)}$$

$$= \frac{5}{t \text{ life } (t)} \quad (M_1(t) + 2\Delta_1) \qquad (2)$$

Therefore, by assembling equations (1) and (2):

$$SM_1(t) = \left[M_1(t+1) - M_1(t)\right] \left(1 + \frac{2}{t \text{ life } (1)}\right) + \frac{5M_1(t)}{t \text{ life } (1)}$$