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INDUSTRIAL DEVELOPMENT AND CONSULTING BUREAU

- PHASE I

DP/KUW/71/507

(R) KUWAIT.

Technical report:
FEASIBILITY STUDY ON THE MANUFACTURE
OF PETROPROTEIN . (1977).

Prepared for the Government of Kuwait by the
United Nations Industrial Development Organization,
executing agency for the
United Nations Development Programme

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United Nations Development Programme

INDUSTRIAL DEVELOPMENT AND CONSULTING BUREAU - PHASE I

DP/KUW/71/507

KUWAIT

Technical Report: Feasibility study of the manufacture of petroprotein

Prepared for the Government of Kuwait
by the United Nations Industrial Development Organization,
executing agency for the United Nations Development Programme

Based on the work of Richard J. Young, petroprotein expert

United Nations Industrial Development Organization
Vienna, 1977

Explanatory notes

References to dollars ($) are to United States dollars, unless otherwise stated.

The monetary unit in Kuwait is the dinar (KD). One fil is KD 0.001. During the period covered by the report, the value of the KD in relation to the United States dollar was $US 1 = KD 0.303.

A full stop (.) is used to indicate decimals.

A comma (,) is used to distinguish thousands and millions.

References to "tons" are to metric tons, unless otherwise specified.

The following abbreviations of organizations are used in this document:

BP	British Petroleum
CMEA	Council for Mutual Economic Assistance
EEC	European Economic Community
ICI	Imperial Chemical Industries
IUPAC	International Union of Pure and Applied Chemistry
KDC	Kuwait Dairy Company
KNPC	Kuwait National Petroleum Company
KUPCO	Kuwait United Poultry Company
LTT	Livestock Transport and Trading Co.
PAG	Protein-Calorie Advisory Group of the United Nations System
PIC	Petrochemical Industries Corporation

Besides the common abbreviations, symbols and terms, the following economic and technical abbreviations have been used in this report:

BHP	brake horsepower
BL	battery limits
BOD	biochemical oxygen demand
COD	chemical oxygen demand
c.i.f.	cost, insurance, freight
FCR	felled conversion ratio
f.o.b.	free on board
h	hour
ha	hectare
kWh	kilowatt-hour
LDPE	low-density polyethylene
LPG	liquefied petroleum gas
MMBtu	million British thermal units
p.a.	per annum
SCF	standard cubic feet
SCP	single cell protein
tcal	toncalorie
t/d	tons per day
t/h	tons per hour
t/yr	tons per year

ABSTRACT

This is the report of a mission to Kuwait undertaken as part of the United Nations Development Programme (UNDP) project "Industrial Development and Consulting Bureau" (DP/KUW/71/507) of which the United Nations Industrial Development Organization (UNIDO) is the executing agency.

Several processes have been developed for the manufacture of single cell protein (SCP) from hydrocarbons. SCP is intended for use as animal (mainly chicken) feed in which it will replace part of the natural protein supplements at present used. The principal such protein supplement is soya bean meal, the price of which determines the price of all other supplements including SCP.

The feedstock in all the commercially important SCP processes is either n-paraffin (separated from gas oil) or methanol (synthesized from hydrocarbon, usually natural gas). If an SCP plant were built in Kuwait, it would be necessary to build a feedstock plant as well.

It is technically feasible to build and operate an SCP plant in Kuwait. It would be necessary to use refrigeration cooling (by standard package units) at additional investment and operating cost.

The higher education institutions in Kuwait do not at present produce the specialist technicians and technologists needed for SCP plant operations, which would therefore initially require expatriate staff. The institutions are however confident that they can arrange curricula to produce the appropriate Kuwait staff in due course.

The minimum economic plant capacity has been shown to be 300,000 tons per year (t/yr). The domestic market will be only 5,000 t/yr in 1981 (the earliest possible commissioning date) and will increase only slowly thereafter; nearly all the plant output would be exported. The biggest plants in operation and under construction in the world are to make 100,000 t/yr, but it is believed that a 300,000-t/yr plant may be built in Europe in the 1980s.

The estimated cost of SCP made in Kuwait by the British Petroleum (BP) process would be about 70% higher than the current price of soya meal imported into Kuwait (for the same amount of contained protein) because of the high cost of the paraffin feedstock (taken at current commercial value) and the rather low protein content of the yeast micro-organism. It is expected that similar Japanese processes will also be costly for the same reasons.

The conservatively estimated production cost, including 15% return on the equity investment, of SCP made by the Imperial Chemical Industries (ICI) process using methanol feedstock (at commercial price) is found to be slightly higher than the current c.i.f. price of soya meal used in the domestic market, comparison being made on a contained protein basis. Other processes using methanol may have similar costs. The cost difference is within the margin of accuracy of the estimates.

The export tonnage of 295,000 t/yr is only a fraction of one percent of the total amount of protein supplement that is currently traded in the world; but it has not been possible during the present study to identify the export markets and to determine the shipping costs to them. It is likely, however, that the Kuwaiti f.o.b. price will be at least 10% below the estimated production cost (which, however, may have a 10% margin of error).

The cost estimate has been made using a gas price of $1.00/MMBtu (on the advice of the Ministry of Oil, to reflect a future value when gas is no longer in surplus), the standard electricity price of 0.67 cents per kWh, and a loan interest rate of 8%. If the quoted Shuaiba site prices of 3.5 cents per MMBtu and 0.33 cents per kWh are used together with a concessional loan interest rate of 5%, then the estimated production cost of SCP is reduced by 10%.

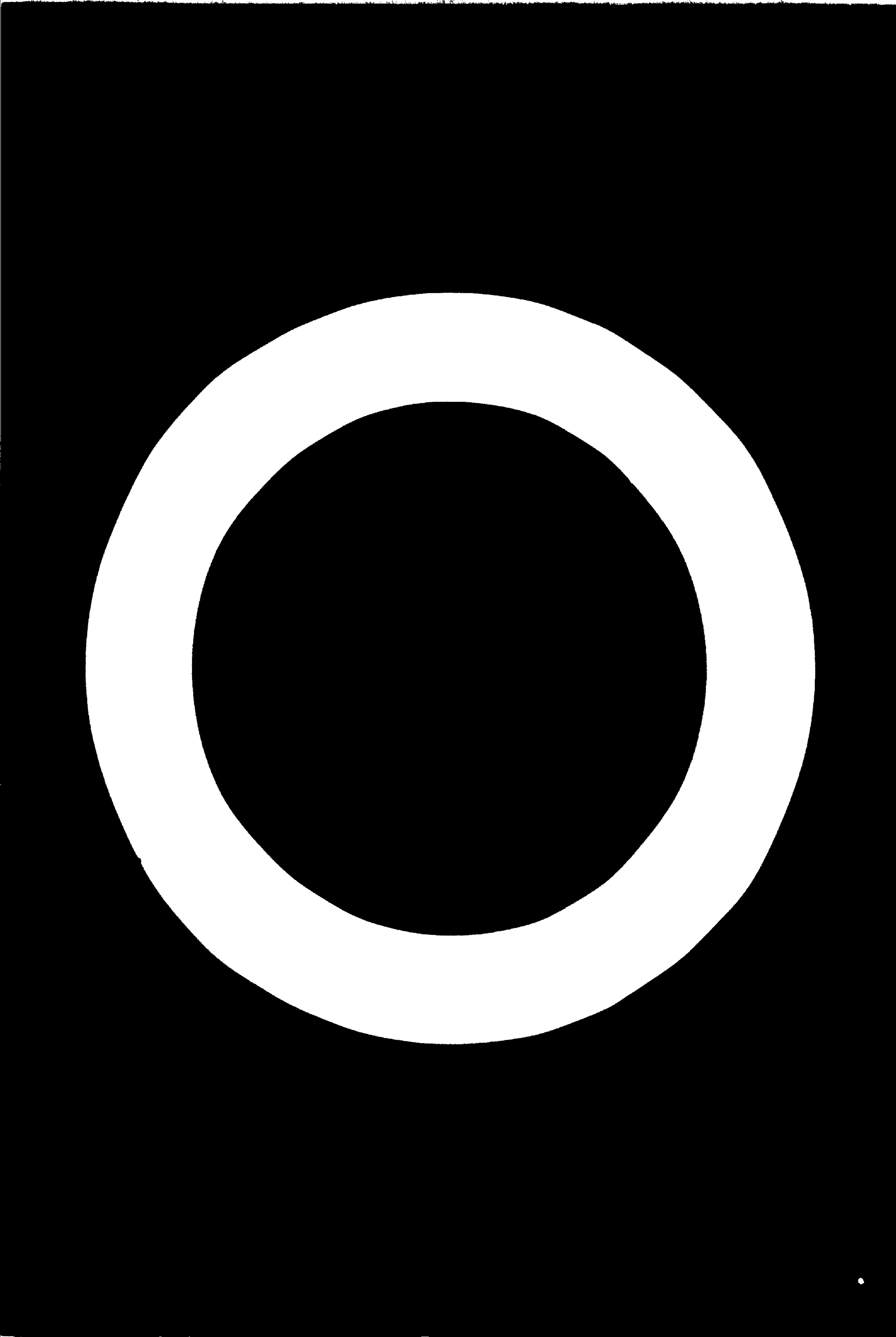
Thus, at current prices the estimated SCP production cost (including return) has been found to be quite close to the selling price at which it can compete with soya meal: but because of the limited accuracy of the estimates, it is not possible to be certain of the economic viability of the project at the present time. However, as the world's demand for food increases and the "protein gap" develops, soya meal prices will rise (according to the World Bank and other authorities). A Kuwaiti SCP plant would seem certain to become profitable in the future, perhaps after 1985. Because of excellent infrastructure and absence of taxation, SCP could be produced more cheaply in Kuwait than in most other oil-producing countries. By 1985 there will be several large SCP plants in operation in the world, including perhaps one of 300,000 t/yr.

It is recommended that further consideration of a Kuwaiti SCP plant be deferred for the time being because of its present uncertain profitability;

but in view of the fact that certain profitability is likely to be achieved in the future, estimates should be updated from time to time using projected costs as far as possible. New technologies should be studied as they become available; and close attention should be paid to the problems of export marketing and export realizations, matters which could best be investigated in co-operation with international feed commodity dealers.

The investment cost (at present prices) of a 300,000 t/yr SCP plant is $240 million, and of the associated methanol plant $120 million. The total investment is similar to that required either by the projected aromatics plant or by the projected ethylene plant. It is recommended that relative priorities for all these projects be established in order to assist in determining the likely commissioning date of a SCP plant.

Recommendations are made, based on experience in other countries, concerning the establishment of an interdepartmental policy committee and a multidisciplinary executive committee to supervise and plan any future active SCP project.



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INTRODUCTION

This is the report of a mission to Kuwait undertaken as part of the United Nations Development Programme (UNDP) project "Industrial Development and Consulting Bureau" (DP/KUW/71/507) of which the United Nations Industrial Development Organization (UNIDO) is the executing agency.

A. Background information

Kuwait is a major producer of petroleum and associated gas. In 1974 the sale of upwards of 110 million t/yr of crude petroleum accounted for some 83% of the State's revenue from exports, the sale of refined products and petrochemicals provided another 16%. State revenues would be increased if a greater proportion of its petroleum resources were increased in value by refining or by conversion into petrochemicals before export.

Kuwait is at present heavily dependent upon imports of food to sustain its population of about one million. In 1975 food accounted for 15% of the import bill. Of the protein foods nearly all red meat is imported. Local broiler and egg production at present amount to only 50% and 15% of consumption respectively. Nearly all chicken feed materials are imported.

There are firm plans to increase broiler and egg production so that Kuwait will become almost self-sufficient in these foods in about five years time. The requirement of chicken feed, including protein supplements, to sustain this expanded production will increase about six times. There are also tentative plans to establish local production of lamb and mutton. Most of the feed for meat production, including nearly all the protein component, will have to be imported in the absence of any local source.

It is against this background - a desire to up-value a higher proportion of petroleum resources before export and to reduce Kuwait's dependence on food imports - that the possible manufacture of single cell protein (SCP) from hydrocarbons appears immediately attractive.

In 1971 SODETAG, a French company, produced for the Kuwaiti Government a "Five years development programme for export-oriented industries". The report recommended that, in a second phase of development, SCP should be made by the British Petroleum (BP) process (then at an advanced state of development) from the gas oil fraction of petroleum. This process was abandoned by BP in 1976 because of technical difficulties. The costs given by SODETAG are not relevant to today's conditions because of the large increase of oil prices that took place in 1973.

In 1976, UNIDO in a report "Development prospects of petrochemical industries in Kuwait" saw the erection of an SCP plant as a possibility in the period 1983-1990, and recommended that a feasibility study be undertaken about 1980.

In November 1976 UNIDO submitted a paper "Future role and development trends in petrochemicals" to the first Latin American Petrochemical Congress in Argentina in which it was noted that the world protein output will need to be increased by 59% (54 million tons) by 1990 and that, provided they can be made profitable, SCP processes "may yet prove to be one of the brightest prospects for alleviating the world protein shortage".

At the end of 1976 a 100,000-t/yr SCP plant, using a second BP process employing normal paraffin feedstock produced in a separate process from gas oil, came into operation in Sardinia, and Imperial Chemical Industries (ICI) started the construction in the United Kingdom of Great Britain and Northern Ireland of a plant, which will be operational at the end of 1979, to make 55,000 t/yr of SCP from methanol feedstock (produced from natural gas). There are no present plans to produce either n-paraffins or methanol in Kuwait, but there are no technical obstacles to prevent their being made. All other SCP processes under development that are likely to have commercial significance use either n-paraffin or methanol feedstock.

In the current study, it is assumed that the SCP plant will be commissioned in 1981; this is in fact the earliest date at which this could be achieved. It is suggested that the report be updated from time to time so that it remains valid for any later commissioning date.

B. Organization and programme of work

The duties of the expert were (in summarized form):

(a) To make a preliminary assessment of the potential viability of the proposed petroprotein project from the technical, economic, marketing and financial points of view;

(b) To make concrete proposals regarding strategy and future implementation plans;

(c) To assess the possibility of a domestic animal agro-industrial complex as a potential use of the petroprotein product.

The assessment of viability and proposals for future strategy are given in this report; no recommendations about an animal agro-industrial complex have been made because any practicable scheme would consume only a small fraction of the output of an SCP plant of the size recommended in this report.

From 21 December 1976 to 2 January 1977 the expert was engaged in preliminary studies in the United Kingdom:

(a) Production of a plan of work and an explanatory document "Planning of a study of the feasibility of manufacturing SCP" (annex I.A), copies of which were submitted to the backstopping officer in the Chemical Industries Section of UNIDO in Vienna and to the Project Manager in Kuwait;

(b) Production of a questionnaire (annex I.B);

(c) Visit to the Licensing and Joint Venture Manager of BP Nutrition Ltd. (formerly BP Protein Ltd.) (annex II.C.13);

(d) Visits to three international commodity dealers in London to discuss their possible marketing of the export surplus from a Kuwaiti SCP plant (annex II.B.6). Correspondence was initiated with a fourth dealer (Ralston Purina) in Brussels;

(e) Visit to the Trade Section of the Bulgarian Embassy in London to discuss the possible exchange of SCP and meat between Kuwait and Bulgaria (annex II.B.7);

(f) Discussions with two firms of industrial refrigeration engineers to ascertain the nature, investment cost and running cost of equipment that would be needed to cool the fermenter of a SCP plant (annex I.F.).

On 3 January 1977 the expert travelled to Vienna for briefing on 4 and 5 January.

On 6 and 7 January 1977 the expert travelled to Kuwait and, after visiting the UNDP offices at Shuwaikh, started work with the Industrial Development and Consulting Bureau of the Ministry of Commerce and Industry.

I. FINDINGS

The study was carried out generally according to the plan drawn up in the preparative period, and is reported below under approximately the same headings. Information was obtained from government statistics and through visits to government departments, official bodies and private firms. Visit reports are given in annex II.

A. Market

Although ultimately SCP may be used as human food, for the forseeable future it will be used only as a protein supplement in compounded animal feeds in partial or complete replacement of the natural protein supplements currently used. The value of SCP will be the same as that of a natural protein supplement of the same nutritional value. The nutritional value of SCP can be determined from its analysis by methods well-known to compounders of animal feed. It is found that the value of SCP is determined mainly by its crude protein content. However, SCP also contains valuable nutrients such as phosphate and the limiting amino-acids methionine and/or lysine at levels that permit the feed compounder to reduce the quantity of these nutrients that he normally has to add to his formulation; some additional value can therefore be attributed to SCP over and above that calculated from its crude protein content. This additional value amounts however to only a few per cent and has been ignored for the purposes of this preliminary feasibility study, in which values calculated from the crude protein content only are used.

The natural protein supplements are of either vegetable or animal origin. In 1974 world consumption was:

	Million tons
Fish-meal	4
Soya bean meal	31
Cotton seed meal	7
Rape-seed meal	3
Meat meal	4
Sunflower seed meal	5
Ground-nut meal	4

Much more protein from soya (in the form of soya meal) is used than any other source, with the effect that the price of soya (produced mainly in the United States of America but also to an increasing extent in Brazil) determines the price of all other protein supplements, and will determine the price of SCP.

1. Domestic market

Broilers

Information on broiler consumption, production and imports has been obtained from the 1975 government foreign trade statistics, the Department of Agriculture of the Ministry of Public Works (annex II.D.16), and the Kuwait United Poultry Company (KUPCO). The figures are not entirely consistent, but the broad picture is:

	1976 (millions)	1981 (estimated) (millions)
Consumed	16	20
Produced in Kuwait	5	20
Imported	11	-

In Kuwait, the average selling weight of a prepared broiler is 1 kg, corresponding to about 1.35 kg live weight. Assuming a normal feed conversion ratio (FCR) of 2.2 kg of feed per 1 kg of live weight gain, the production of 20 million broilers in 1981 will need 60,000 tons of feed.

A very large number of experiments have been carried (mainly in Europe) in which SCP has been included in broiler diets at various levels in partial replacement of natural protein. The experimental diets and the control diets were formulated so as to have the same energy value and amounts of protein, limiting amino-acids, minerals and all other important nutrients. It was found that the maximum feed conversion efficiency (1/FCR) and maximum rate of growth was obtained when about 5% of SCP was included in the diet. If all the soya meal is replaced by SCP, no improvement in performance above the control (with no SCP) was found, and there might indeed be a depression of performance. In Europe, it is proposed to use about 5% of SCP in broiler diets and the same figure has been assumed for Kuwait. (It is suggested, however, that nutritional experiments should be carried out in Kuwait to determine the optimum level of

SCP inclusion using the feed components normally used in Kuwait and under Kuwaiti climatic conditions). Countries which find it difficult to pay for United States soya, or which wish to reduce their dependence on it, may choose to use higher percentages of SCP and accept sub-optimal performance.

At the 5% level, the potential use of SCP in 60,000 tons of broiler feed in 1981 is 3,000 tons.

Because imports of broilers will have almost ceased in 1981, any further increase in broiler production beyond this date will depend upon the natural increase of local demand and on a possible export trade in broilers. Because this study examines only conditions in 1981, no attempt has been made to quantify the corresponding potential increase in demand for SCP: it will approximate to the natural growth of population.

Eggs

From information gathered from the same sources, the picture is approximately:

	1976 (million)	1981 (estimated) (million)
Consumed	200	235
Produced	30	235
Imported	170	-

The average weight of an egg is 60 g. Assuming a normal FCR of 2.3 (kilogram of feed per kilogram of eggs), the consumption of feed by laying hens is calculated to be 32,000 tons. As with broilers, expansion of use beyond 1981 will depend on increase in consumer demand for eggs and a possible export trade in eggs.

Milk production

Information was obtained from the Livestock Transport and Trading Co. (annex II.B.11), the Department of Agrioulture (annex II.D.16) and the Kuwait Dairy Company (annex II.B.12).

The Kuwait Dairy Company (KDC), is the only producer of fresh milk in Kuwait. At present it produces in a central establishment and ten associated farms a total of 16 tons per day of milk from 1,600 milking cows. KDC mixes its own feed from mainly imported materials which include 845 t/yr of vegetable protein concentrate containing an average 40% of crude protein.

In the next five years, the number of cows will be increased to 5,000, producing 50 t/d of milk and using probably 2,500 t/yr of 40% vegetable protein. Even if as much as 30% of this were replaced, the use of SCP (containing 72% crude protein) would be only 400 tons in 1981.

However, 50 t/d of milk will be only about 30% of the milk consumed in 1981, so that there will be scope for further expansion of the dairy industry with a resultant increase in the potential demand for SCP which will, however, remain quite small.

Milk replacer is fed to calves between the ages of 10 days and 3 months. SCP can be used to the extent of 5% (but not more) in the formulation of milk replacer. The potential use of SCP in milk replacer is negligible - only 1 or 2 tons per year.

Meat

Lamb and mutton are the preferred sources of protein in Kuwaiti diet. At present all meat is imported - about 26,000 t/yr of live animals and 30,000 t/yr of prepared meat.

The Livestock Transport and Trading Co. (which is the sole importer of live animals) plans to set up in the next five years a prototype farm containing 25,000 breeding ewes which are expected to produce 37,000 lambs per year. Lambs will be killed for meat at a live weight of 52 kg and a carcase weight of 25 kg - a total of 2,000 tons live weight, 920 tons carcase weight. A very rough calculation (annex I.C) suggests that SCP might be used in the diets of the lambs and breeding ewes to the extent of 1,000-2,000 t/yr. The prototype farm will produce only a small fraction of Kuwait's meat requirements, so there is scope for expansion of meat production beyond 1981 with a consequent increase in the usage of SCP.

The project for a prototype meat farm is not yet firm, and cannot, therefore, be considered a certain outlet for SCP.

Marketing of SCP

There are three privately owned feed manufacturers in Kuwait. Two of them - El-Homaizi and Animality Wealth - were visited (annex II.B.9 and B.10). Their estimates, and that of KUPCO (annex II.B.8) agree that their current total production of animal feed is about 20,000 t/yr. The manufacturers produce mainly for the broiler and egg industry, which is also at present privately owned.

The current production of 5 million broilers at 1.35 kg live weight and an FCR of 2.2 requires 15,000 t/yr of feed. The current production of 30 million eggs of 60 g at a FCR of 2.3 requires 4,000 t/yr of feed. The total, 19,000 t/yr, is in excellent agreement with the estimated 20,000 t/yr produced.

The expansion of broiler and egg productions in the next five years will be carried out by KUPCO, a state-owned organization, which will produce its own feed. Production of feed has already started at the design rate of 10 tons per hour (t/h).

KDC mix their own feed for milk production.

The marketing of SCP to domestic feed manufacturers, probably no more than five in all, should present no difficulties, particularly if some technical support can be given by, for instance, the Department of Agriculture.

Summary of domestic market

The "likely maximum" sales of SCP for the production of broilers, eggs and milk in 1981 are:

		Tons
Broilers		3,000
Eggs		1,600
Milk		400
	Total	5,000

A further 1,000-2,000 t/yr might be required for meat production if the project for a prototype sheep farm goes ahead.

The above total would be reduced if there is resistance to change, which is most likely to occur in the private sector, and might be increased by government pressure or incentives to use locally produced protein.

2. Export market

It is shown later that the minimum economic size of plant will be about 300,000 t/yr. The domestic market will be only 5,000 t/yr; the surplus of 295,000 t/yr will have to be exported.

This quantity will in 1981 be a high proportion of the amount of SCP then being made in the world, but it will be very small in relation to the total amount of protein meals then sold in the world for use in animal feeds. The historical demand for meals in 1970, and the forecast demands for 1980 and 1990 (unpublished work by ICI) in millions of tons of crude protein per year are:

	1970	1980 (est.)	1990 (est.)
		(million tons)	
European Economic Community (EEC)	6.1	8.9	11.2
United States	6.7	8.4	9.9
Japan	1.5	2.2	3.5
Other developed countries	2.2	3.7	4.8
Developing countries	3.2	5.8	8.8
Union of Soviet Socialist Republics	2.0	4.3	7.5
Eastern Europe	1.0	2.4	4.4
Total	22.7	35.7	50.1

The export surplus of 295,000 t/yr of SCP containing about 200,000 t/yr of crude protein would in 1980 amount to only 0.6% of the total traded protein.

It would appear, then, that the export surplus could be sold in replacement of protein meals, at an equivalent price, without disturbing the market. The problem is to decide how this can best be achieved. In seeking a solution it is necessary to note some constraints:

(a) It will probably be impossible to sell SCP into the United States where soya is cheap and to which freight costs will be high;

(b) All SCP processes of commercial significance have been developed either in Europe or in Japan, primarily to exploit the local market and only secondarily for licensing. Each process owner is likely to exclude his own production and sales territory from the territory of a licence. The exclusion of EEC in particular will significantly limit the market available to Kuwait;

(c) Public concern about the safety of SCP has been expressed in certain countries, particularly in Italy and Japan. The fears are certainly unfounded; but until they have been allayed, these countries must be excluded as possible markets.

Nevertheless, even with the exclusion of Italy, Japan and the United States and possibly the rest of EEC, about half the world market will still be available for exploitation. This remaining market will, however, be spread over a wide area of the globe, and will in general be composed of less developed countries where it may be difficult to obtain any premium value for SCP above that represented by its crude protein content.

The following methods of export marketing have been considered:

Kuwaiti organization. Kuwait already markets its own production of urea and ammonia. However, marketing of SCP by Kuwait is not recommended because:

(a) It would require the establishment of offices or representatives in many countries, each capable of providing the necessary technical service for making and sustaining sales;

(b) It would be in competition with existing international protein traders and with process owners marketing their own product.

Process owner. The process owners intend to market their own products in their own territories and might perhaps undertake the marketing in other territories of the output of licenced plants.

(a) The process owner would be able to supply the necessary technical support and, in the case of ICI and BP, would have a network of sales offices in all countries. Japanese process owners would probably operate through established international Japanese trading companies;

(b) The process owner might sell into his own sales territory in order to supplement his own production if the occasion arose and if it were economic to do so;

(c) However, from time to time there would be competition for sales between the Kuwaiti product and that of the process owner; such conflicts would be resolved by the process owner in his favour.

It is recommended that, in any extension of this study, discussions be held with process owners to ascertain what assistance they might give with export marketing.

International commodity trader. A number of very large companies already handle throughout the world the very large trade in natural protein feed supplements as well as other commodities. Preliminary discussions have been held with three of these traders (annex II.B.6) who have expressed interest in handling SCP as well.

(a) The trader already has a network of sales offices and sales outlets and is in a position to supply the required technical services;

(b) It would be better to work in co-operation with these powerful organizations than in conflict with them;

(c) However, there are dangers in having only one customer for one's product. It would be advisable to divide the business between say, two traders with renogatiation of contracts every two years or so, or to sell say 80% of the output to one trader, with 20% sold as spot lots.

It is recommended that further discussions be held with traders to explore the possibility of their marketing Kuwaiti SCP, and to ascertain possible terms and conditions.

B. Technology

Several corporations have developed processes for the large scale production of SCP to the point of actual or potential commercial exploitation. All the processes are basically similar and comprise the following steps:

(a) Sterilization of the raw materials which are:

(i) A carbon-containing substrate which supplies the carbon present in the SCP product and, through oxidation, the energy required by the fermentation process;

(ii) Oxygen, in the form of air, which supplies the oxygen present in the SCP product and, through oxidation of part of the substrate, the energy required by the fermentation process;

(iii) Ammonia which supplies the nitrogen present in the SCP product;

(iv) Various minerals needed by the micro-organism for growth and reproduction. Of these, phosphorus in the form of phosphate is the most important; all other minerals are added in trace amounts only;

(b) Growth of a micro-organism in an aqueous medium in a fermenter supplied continuously with sterilized raw materials. Considerable quantities of heat must be removed from the fermenter;

(c) Separation ("harvesting") of the micro-organism from a stream of medium removed continuously from the fermenter;

(d) Drying of the separated micro-organism and, if necessary, granulation or grinding to produce the SCP product in the required form.

The developed technologies differ according to:

The feedstock used as carbon source

The micro-organism used

The design of the fermenter
The method used for harvesting.

The developed processes are (in approximate order of development):

1. British Petroleum uses normal paraffin feedstock (which is separated from the gas oil fraction of petroleum by a proprietary molecular sieve process); a yeast micro-organism; stirred fermenters; and harvesting by centrifuges. The temperature of fermentation is 35°C. The pH of fermentation is about 4 and the fermenter is accordingly constructed of stainless steel. BP has a large pilot plant (4,000 t/yr) at Grangemouth, Scotland, United Kingdom; and in December 1976 started operation of a 100,000-t/yr plant constructed jointly with ANIC in Sardinia, Italy. The joint company is called Italproteine.

BP formerly operated a process in which yeast was grown on a gas oil feedstock. Only the normal paraffin component of the feedstock was consumed, and the unconverted part of the gas oil (which had an improved pour-point because of the removal of n-paraffins) was separated from the SCP in a final solvent extraction stage. This process was operated in a 20,000-t/yr plant in Lavera, France. The plant was shut down in 1976 (because, it is believed, of difficulties with the final separation process) and development of the process has been abandoned.

2. Kyowa Hakko (Japan) has a process based on BP technology. No commercial plant has been built.

3. Kanegafuchi (Japan) has a process which uses a n-paraffin feedstock; an air lift fermenter (in which circulation of the contents of the fermenter is brought about by the injection of the air needed for fermentation); a yeast micro-organism; and harvesting by centrifuge. The fermentation temperature is probably about 35°C and the fermenter is made of stainless steel. Kanegafuchi was about to construct a 50,000-t/yr plant in Japan in 1973, and had contracted to sell almost the entire output of the plant to Zen-Noh (the Japanese farmers co-operative) for use as chicken and fish food, but consumer objections in Japan caused them to postpone indefinitely their plans. Kanegafuchi has licensed their technology to Liquichimica (Italy) who have built a 100,000-t/yr plant which is believed to be complete and ready for operation. Since then, the Japanese Government has banned further licensing of the technology because of the consumer objections.

4. Dai Nippon Ink (Japan) has a process which uses n-paraffin feedstock and yeast. Dai Nippon Ink (like Kanegafuchi) was believed ready to build a plant in 1973 but was prevented by consumer objections. The technology has been licensed to Romania where a plant is under construction. Further licensing of the technology has been stopped by the Japanese Government.

5. AMOCO (United States) has a process using ethanol feedstock and yeast; a small plant is in operation and the product is being sold for incorporation in human food.

6. Imperial Chemical Industries (United Kingdom) has a process using methanol feedstock; bacteria as the micro-organism; and a special design of air-lift fermenter. Harvesting is by agglomeration in which the bacteria are caused to adhere together in lumps so that they may be separated by flotation. The separated product may optionally be further dewatered in a small centrifuge installation. ICI is constructing a 55,000-t/yr plant at Billingham, England, United Kingdom, which will come into operation at the end of 1979.

7. Mitsubishi Gas Chemical (Japan) is developing a process using methanol feedstock and a yeast micro-organism. Bacteria have also been considered. A large pilot plant at Niigata has been in operation for about two years. The future exploitation of the process is uncertain because of the Japanese Government attitude already referred to.

8. The USSR has developed a process using n-paraffins and yeast, which is believed to be in operation on the commercial scale. The USSR is, however, also considering the use of BP and Liquichimica (Kanegafuchi) technology.

It is recommended that any SCP plant in Kuwait should use a technology that has already been demonstrated on the commercial scale. It is further recommended that the Amoco process (using ethanol) be not considered because of the high cost of the feedstock. Russian technology is also to be excluded at this stage because of uncertainty about its status. This leaves the BP process as the only operating one to be considered.

However, the ICI process will come into commercial operation in 1979 and, because a final decision about the Kuwaiti plant may possibly not take place before that date, it is recommended that the ICI process be also considered. The Liquichimica (Kanegafuchi) and Romanian (Dai Nippon Ink) plants will also be operating before 1979 but, because the licensing of these technologies is at present forbidden by the Japanese Government, it has not so far been possible to obtain even non-confidential evaluation information from the process owners.

Consideration of these processes must therefore be delayed until the present Japanese Government policy is changed. The processes are likely to prove similar to that of BP.

The Mitsubishi Gas Chemical process is also subject to the same ban, and is not yet fully developed, but should be given serious consideration when available because it shares with the ICI process the likely advantage of using methanol feedstock.

For the reasons given, this report deals only with the BP and ICI processes. A subsequent updating of the study must take into account any further demonstrated processes that may have become available. Each is representative of a different class of process; later processes are likely to fall into one class or the other.

1. Relative merits of BP and ICI processes

The BP process has been under development for longer than that of ICI, and can now be seen in operation. Even after the ICI process has come into operation in 1980, BP will have the advantage of three years commercial operation.

Both BP and ICI are large commercial organizations. Each has extensively tested its product for nutritional and toxicological characteristics. Each has large research facilities and each is in a position to provide the technical back-up necessary to ensure the continued successful operation of a commercial plant.

ICI process uses methanol feedstock which can be made from any fuel, although at the present time it normally is made from natural gas because this is the cheapest. Methanol is very easily purified to a high standard. The bacteria used in the ICI process provide an SCP of higher protein content than the yeast of the BP process. Some of the critical amino-acids are at a higher level in the ICI product. The special ICI fermenter can be extrapolated to very large unit sizes, thus enabling advantages of scale to be obtained. The oxygen efficiency (the proportion of the oxygen in the air introduced to the process that is used in the process) of the ICI process is higher than in the BP process, thus reducing the investment and running costs for compression.

The fermenter is constructed in carbon steel instead of stainless steel. For reasons given, it is likely that the investment cost of an ICI plant will be less than that of a BP plant of the same capacity. However, investment cost data supplied by the two companies are almost identical.

The Ministry of Oil has recommended that, because all gas in Kuwait is associated gas and therefore restricted in supply, any SCP produced in Kuwait should use n-paraffin feedstock provided the cost of producing SCP is no higher than by the gas/methanol route; but if the gas/methanol route is cheaper, then it should be used.

Adaptation to Kuwaiti conditions

The fermenter will employ the same micro-organism under the same conditions as were found to be optimum by the process owner during his development of the process. Provided the conditions can be maintained, therefore, the performance of the fermenter will be exactly the same.

Outside the fermenter some changes will be needed in the plant design that was developed for Western European conditions:

(a) Heat from the fermenter cannot be removed by heat exchange with air, a circulating evaporative cooling water system, or by seawater because of the high temperatures that prevail during much of the year in Kuwait. Refrigeration cooling (with discharged heat transferred to sea water) will be used instead at additional investment and running cost;

(b) If it is shown that SCP deteriorates when subjected to the high temperature and humidity of the Kuwaiti summer, then air conditioning of the stores will be needed. The Kuwait Institute of Scientific Research is proposing to do some storage tests;

(c) Most of the plant output will be exported in bulk. Unlike a European plant, where product will be leaving the plant continuously in truck-loads or in containers, the product from a Kuwaiti plant will leave only intermittently in ship-loads. Increased storage capacity may be needed.

2. Licence fee and terms

Each process owner has made a very large investment in research and development - a minimum of $20 million is believed necessary to bring a process to the point of commercial exploitation - and will try to recover some of his outlay by licensing. However, each process owner has developed his process primarily for his own use and will seek to protect his position as a producer by, for instance, excluding the area where he produces from the territory of the licence agreement. Other restrictions are:

(a) The Japanese Government does not at present permit the licensing of Japanese SCP technology;

(b) Some process owners (including ICI) will not consider licensing until the process has been operated commercially;

(c) Some process owners may wish to exploit their technology only by licensed joint ventures. This requirement may lead to difficulty because:

(i) A project may be profitable by Kuwaiti criteria because of the absence of tax on profits, but unprofitable to a foreign partner because his remitted profits will be taxed in his own country;

(ii) The terms demanded by a foreign investor (for instance, equity share, management control, distribution of profits) may be contrary to Kuwaiti law or otherwise unacceptable to the Kuwaiti partners;

(iii) So long as the process owner has a policy of investing in his own technology, he will limit the number of licensed joint-ventures in which he participates in order to avoid competition between his separate investments and maximize his over-all profits.

For the above reason, it must not be assumed that any desirable technology can automatically be obtained on reasonable terms. It is recommended that, as soon as the Kuwaiti authorities have decided in principle to have an SCP plant, discussions should be started with BP and ICI about possible licence terms, and that the discussions be extended to the owners of other processes as they enter the commercial stage.

3. Local technical resources

SCP plants employ advanced technology. Although in many ways an SCP plant is similar to any other modern chemical plant, there are two important differences:

1. A new concept of "sterile engineering" is applied to ensure that the plant can be made sterile before start-up and that ingress of organisms other than the chosen one is completely prevented during operation. Any passage that is bigger than the micro-organism (about 1 micron in the case of bacteria) is a likely contamination route. Foreign micro-organisms can travel against a pressure gradient and counter to fluid flow. To a very large extent sterility is achieved by correct design of the plant; but additionally operation and fermenter maintenance must be of an unusually high standard. (It may be noted

that contamination of a bacterial system operating at pH 7 (such as the ICI process) occurs more readily than contamination of a yeast system operating of pH 4 (such as the BP process); but the BP process has mechanical stirrers which require sterile glands whereas there are no moving parts in the ICI process.)

2. New concepts of microbiological engineering are involved:

(a) Continuous microbiological monitoring (at technician level) of the fermenter contents and of the product is necessary to determine among other things whether contamination has occured;

(b) An understanding is needed (at plant technologist level) of the kinetics of microbiological growth and reproduction, and of changes in the behaviour of the micro-organism that may be caused by variation of fermenter conditions, in order that deterioration in plant performance may be promptly recognized and diagnosed and remedial action taken. The process owner will, during the development of the process, have acquired the necessary knowledge to diagnose most changes and will pass it on by manuals and by training;

(c) A back-up (at research microbiologist level) is needed to enable microbiological problems, other than the routine ones of (b) above, to be promptly solved. The process owner will be able to provide such a problem-solving function himself (and indeed it is essential that he has an obligation to do so under the terms of the licence agreement) but a local back-up, probably at a local research institute or university, is also necessary if loss of plant output through delay is to be avoided.

It is probable that not all the managers, scientists and skilled personnel necessary for the special functions described in (a), (b) and (c) above could be supplied by Kuwait at the present time. If the SCP project goes ahead, it will be necessary to acquire and/or train such personnel. It is recommended that:

1. The ultimate back-up in problem solving be provided by the process owner for an indefinitely long period. The process owner has in his possession the original research information, experience in the operation of his own plants, knowledge of the problems encountered in the operation of other licensed plants and the solutions to them, and the equipment, apparatus and personnel needed for problem-solving. This continuing involvement of the process owner should be secured under the terms of a joint venture agreement or a management contract.

2. Immediate microbiological problem-solving, where appropriate, should be carried out by a designated Kuwaiti institution. The Kuwait Institution of

Scientific Research is already engaged in the study of SCP processes, and possesses suitable laboratory fermenters and a limited number of technologists and technicians to permit some investigative work to be carried out.

3. Specialist technical supervision and control of plant operation should be provided by personnel supplied by the process owner on a diminishing scale during commissioning and for the first one or two years of operation. Such assistance would be secured under the terms of a joint venture agreement or management contract. Kuwaiti scientists and skilled personnel would be trained before commissioning of the Kuwaiti plant on an operating plant of the process owner, and on the Kuwaiti plant after commissioning. It is normal for precommissioning training to be given under the terms of the licence agreement and for the cost to be included in the fee.

4. Training of non-specialist (although not necessarily unskilled) personnel should be carried out by Kuwaiti personnel who have been "trained to train". It is usual for a trainer to be included among the personnel undergoing precommissioning training on the process owner's plant (3, above).

C. Product safety

All the major process developers have very extensively tested their products. "No food or feed product on the market today has been so thoroughly tested for safety" (annex I.D). No pathogenic, mutagenic, teratogenic, carcinogenic or toxic property, or indeed any other harmful characteristic, has been revealed by these tests or by examination of animals used in nutritional tests.

The BP product has been officially approved for manufacture and sale by the regulatory authorities of the EEC countries, Portugal, Spain and Switzerland. ICI has applied for approval of its product in the countries of north-western Europe.

In Italy, approval was given for BP product but later withdrawn. This situation was examined by Professor N. S. Scrimshaw, Chairman of the Working Group of the Protein-Calorie Advisory Group (PAG) of the United Nations System, in his summary of the PAG symposium on SCP for animal feeding held in Brussels in March 1976 (annex I.D). He concluded that the objections raised by the Italian authorities were without foundation and concluded that there were no nutritional or toxicological barriers to the commercial development of SCP of the ICI and BP types.

Objections were raised in 1973 by consumer associations in Japan to the then imminent manufacture of SCP by two or three major Japanese process developers. The objections were not based on facts but amounted to a dislike for the manufacture of food by chemical companies. Because of the objections, the Japanese Government withdrew permission it had already given for the manufacture and sale of SCP in Japan. At this time, the Kanegafuchi process had already been licenced to Liquichimica in Italy, and the Dai Nippon Ink process to Romania. These projects are going ahead, but the Japanese Government has banned any further licensing.

It is recommended that toxicological trials should not be undertaken in Kuwait because of the time, money and other resources required; but instead the Kuwait authorities should approve any SCP that has been examined and approved by the regulatory authority of a major developed country.

2. Industrial

The approval of an SCP by a regulatory authority indicates that it is non-toxic. Like many naturally occurring proteins SCP is an allergen and can cause reactions if inhaled as dust. In the case of the ICI product, there are no reactions if the dust concentration is below 0.1 mg/m^3, some people may be affected at 1 mg/m^3, and many people are affected at 10 mg/m^3. Oil is added to the product to suppress dust, and operators are required to wear masks and goggles in specially dusty situations, such as when cleaning.

SCP is combustible and an airborne dust cloud may explode when ignited as do most powdered cereals and proteins used in feed manufacture. Similar precautions against fire and explosion are needed.

D. Engineering and investment

1. Site selection

The Kuwaiti authorities proposed that the plant be built on the Shuaiba Industrial site, which is on the coast about 50 km south of Kuwait City. The site was inspected and found to be excellent in every respect.

There is a good, uncongested harbour capable of taking dry cargo vessels of up to 47 ft draught, and an oil jetty

Electric power is generated on the site and is available at a very low price

Desalinated water is made using exhaust heat from the power station and is made available as a service

Gas is available on site. Petrochemicals are made on site, and oil products are made in adjoining refineries

Roads are already in existence

Staff and workers housing exists within a reasonable distance

There is still plenty of land available within the site at a very low rental

Cement is made on site

Pumped sea water for cooling is made available as a service

The site is managed efficiently by the Shuaiba authority.

The cost of services available at Shuaiba is given in annex I.E.

2. Design changes

It is necessary to consider what adaptions to imported SCP technology and plant design would be required to make them suitable for Kuwaiti oonditions and circumstances.

(a) In SCP processes, very large quantities of heat must be removed from the fermenter which is at 35°C (BP and similar processes) or 40°C (ICI and similar processes). The very high temperatures and humidity of the Kuwaiti summer make it impossible to use conventional cooling towers or air coolers. Instead, refrigeration will have to be used (at extra investment and operating cost). Heat removal from the sets will be by sea-water cooling. It is shown that standard sets will be adequate for this duty, even at maximum sea-water temperatures; energy and water requirements and investment cost are calculated in annex I F;

(b) Process owners have shown that their products can be stored indefinitely in the temperate climate of Western Europe, but no information is available about the storage properties of SCP under Kuwaiti conditions. It is suggested that storage tests be undertaken. If deterioration is found, then it may be necessary to use air-conditioned stores. No allowance for this has been made in the estimates;

(c) Because of the time taken to obtain spares from manufacturers in the developed countries, it will be necessary to provide additional spares, both installed and non-installed. On the advice of Petro-chemical Industries Corporation (PIC), the cost of additional spares has been included in the factor used to convert European investment cost to Kuwaiti investment cost.

3. Investment cost

It is necessary to carry out, at significant cost, a considerable amount of design work in order to determine accurately the cost of building a plant at a particular location. Such design work has not been done during the present preliminary feasibility study; instead, the cost of a Kuwaiti plant has been determined by adjusting the known cost of a European plant.

It is assumed that the design of the plant within battery limits remains the same.

Consideration has been given to the provision of offsites, the cost of which in a developed country is typically 30%-35% of the battery limit cost. In many developing countries it is necessary greatly to increase the provision of offsites to compensate for the lack of services and other infrastructure. In the case of Kuwait, however, the excellent infrastructure at Shuaiba makes it unnecessary to make any increase, apart from the provision of refrigeration cooling which is treated separately.

The construction cost of a plant in Kuwait is higher than the cost of an identical plant in Europe by about 35% (according to PIC) because of the effects (which are almost equal) of additional freight charges, lower labour productivity, and increased provision of spares. (BP says that the increase is 25%, but their figure does not allow for the cost of additional spares, which is treated separately).

The cost of installing refrigeration must be added; if European estimates are used, then the 35% increase must also be applied.

It is proposed elsewhere that only the BP and ICI processes be considered at the present time. The investment cost of an ICI plant is first estimated, and then the possible cost of a BP plant is discussed.

The investment cost of an ICI plant to make 55,000 t/yr of SCP in the United Kingdom is, in dollars of mid-1976, as follows:

	Million $	Percentage of BL
Battery limits (BL)	25.4	
Offsites	8.1	32
Design, engineering, contingencies, start-up etc.	14.4	57
	47.9	

Note: Feedstock storage is not included. Offsites are unusually low because of the developed nature of the site and the proximity of a methanol plant which will supply the feedstock. Equipment for grinding the product for use as milk replacer is included. This will probably not be necessary in Kuwait.

ICI recommend that an exponent of 0.7 be used for estimating the cost of a plant of different capacity; for a plant of 300,000 t/yr, the cost factor is thus (300,000/55,000) 0.7 = 3.27. The installed cost of refrigeration sets (European conditions) is shown elsewhere (annex I.F) to be $16.2 million. Using the mark-up of 35% for Kuwaiti construction conditions we have:

		Million $
Battery limits (25.4 x 3.27)		83.1
Offsites (35% of 83.1)		29.1
Refrigeration		16.2
Design etc. (14.4 x 3.27)		47.1
	Total	175.5
	Increase by 35%	236.9
	Say	240

BP supplied costs for a 100,000-t/yr plant, also in dollars of mid-1976.

(a) Battery limit cost: $38 million. This is exactly the same as the battery limit cost of an ICI 100,000-t/yr plant, calculated from the cost of a 55,000-t/yr plant by applying the 0.7 exponent;

(b) Offsites (including refrigeration): $10 million - $20 million (26% - 53%) depending on circumstances, BP is justified in stating this wide margin in the absence of detailed knowledge about the location. Offsites including refrigeration but excluding storage in an ICI 100,000-t/yr plant would be 49% of battery limit cost. It appears that the BP allowance for refrigeration is less than ICI's whereas, because of the lower fermentation temperature, it should be more;

(c) Contingencies: 5%-10%. ICI allows 8%;

(d) Spares: $2 million. ICI allows, for the same size plant, about $2.4 million, plus a further allowance in the mark-up for Kuwaiti conditions;

(e) Exponent for extrapolation: 0.75. ICI recommends 0.7. It is reasonable that a higher exponent be used for the BP process because extrapolation to large capacities requires multiplication of fermenters whereas the ICI process uses a single stream fermenter up to at least 150,000-t/yr capacity.

All in all, the BP estimate is quite close to the ICI one; in fact, the battery limit costs are identical. In the estimate below this battery limit cost for 100,000 t/yr is used, and all other costs are calculated using the same factors as for the ICI estimate, except that an exponent of 0.75 is used instead of 0.70 for a 300,000-t/yr plant:

	Million $
Battery limits (BL)	86.6
Offsites (35% BL)	30.3
Refrigeration	16.2
Design etc. (57% BL)	49.2
Total	182.3
Increase by 35%	246
Say	250

Licence fee

It is assumed that ICI would seek a down-payment licence fee of about 5% of the investment cost of the plant i.e. about $5 million in the case of a 100,000-t/yr plant. The ICI fee would probably not include design.

BP quotes $10 million including design (presumably "front end" design) by BP. Such design might be valued at $4.6 million. The BP fee, therefore, seems about the same as ICI; but any fee is determined finally by negotiation.

ICI might also seek a running royalty, whereas BP does not mention one.

Since design charges have been allowed for in the method of estimating both ICI and BP costs, the licence fees assumed, as a percentage of investment cost, will be 5% for both companies.

Working capital

The estimation of working capital requires a proper commercial investigation. However, on certain assumptions, the working capital needed for stocks of raw materials, product in store, and accounts receivable less accounts payable might be, in the case of a 300,000-t/yr plant, $30 million for the ICI process and $35 million for the BP process which has a more costly feedstock.

Capital requirements

The annual depreciation rates are those recommended for Kuwaiti projects, namely, 5% for buildings, 10% for plant, 20% for licence fee. Working capital is not depreciated. Buildings are estimated to be 15% of the fixed capital.

Finance of fixed capital and licence fee will be 70% by loan (assumed 8% per annum (p.a.) interest) and 30% by equity investment (required return 15% p.a.). Working capital will be financed wholly by loan.

Table. Capital requirements for a plant producing 300,000 t/yr of SCP

A. ICI process

Item	Capital		Depreciation		Finance ($ per t/yr)	
	Million $	$ per t/yr	% p.a.	$/t	Loan	Equity
Fixed						
Buildings	36	120	5	6		
Plant	204	680	10	68		
	240	800			560	240
Licence	12	40	20	8	28	12
Working	30	100	-	—	100	—
Total	282	940		82	688	252

B. BP process

Item	Capital		Depreciation		Finance ($ per t/yr)	
	Million $	$ per t/yr	% p.a.	$/t	Loan	Equity
Fixed						
Buildings	38	127	5	6		
Plant	212	706	10	71		
	250	833			583	250
Licence	12	40	20	8	28	12
Working	35	117	-	—	117	—
Total	297	990		85	728	262

Investment in feedstock plants

In the cost estimates that follow, the feedstocks are entered at their current commercial values without reference to their cost of production.

The investment needed for a 500,000-t/yr methanol plant, sufficient to supply a 300,000-t/yr SCP plant using the ICI process would be about $125 million (fixed capital only).

The investment for a 300,000-t/yr plant for the separation of n-paraffins is estimated to be $92 million (fixed capital only). This quantity is sufficient to supply a 300,000-t/yr SCP plant using the BP process. The estimate is based on a 1974 estimate by Compagnia Tecnica Industrie Petrol for a 500,000-t/yr n-paraffin plant in Kuwait by using an exponent of 0.67 and applying the World Bank inflation index to calculate a mid-1976 cost.

E. Production cost and profitability

The required selling price (including return on equity investment) of SCP from a Kuwaiti plant has been calculated for both the BP and ICI processes and the results have been compared. Calculations have been made on a "mature year" basis. The following assumptions have been made:

(a) Fixed capital and license fee financed 70% by loan, 30% by equity investment. All working capital financed by loan;

(b) Loan interest 8%;

(c) Required return on equity investment 15%;

(d) Depreciation:

Depreciation:	Buildings	5% p.a.
	Plant	10% p.a.
	Licence fee	20% p.a.

(e) All raw materials common to both processes entered at the same unit price, i.e. possibly differing quality specifications, have been ignored;

(f) Utility unit costs as quoted by the Shuaiba authority except that a gas price of $1 per MMBtu is assumed, on the advice of the Ministry of Oil, to reflect the possible future value when gas is no longer in surplus, and an electricity price of 2 fils per kWh;

(g) When prices, quantities or efficiencies are known for one process but not the other, the known values are assumed to apply to both processes;

(h) Investment costs for mid 1976 are used. No allowance is made for inflation;

(j) Current raw material prices are used and comparison is made with the current price of soya meal which is $306 per ton c.i.f. Kuwait;

(k) No tax on profits in Kuwait. (Note that a foreign investor would have to pay corporation tax, usually about 50% on his repatriated profits);

(l) A royalty of 3% of selling price is assumed for the ICI process only.

1. Feedstock cost

A current cost of $100 per ton for methanol is used. This is the current market value in Europe and is also a price at which methanol could be made profitably in the Gulf area.

A current cost of $340 per ton for n-paraffin is used. This is the ex-works price at which BP is currently selling from its United Kingdom plant. In the absence of detailed information about the location of markets, it is assumed that n-paraffin could be sold at the same price from a Kuwaiti plant, and that this price is, therefore, its value as feedstock to an SCP plant.

2. Production cost

ICI process, 300,000 t/yr

Variable	$/t SCP	$/t protein
1.72 t methanol at $100/t	172	239
0.056 t P_2O_5 at $500/t	28	39
0.147 t ammonia at $120/t	18	25
Other materials	20	29
1.28 t steam at $5/t	6	8
12.2 MMBtu gas at $1/MMBtu	12	17
2,600 kWh[a/] electricity at $0.0067/kWh	17	23
1,230 m^3 sea water at $0.0067/$m^3$	8	11
4 m^3 pure water at $0.18/$m^3$	1	1
Other services	1	1
Total	283	393
Royalty 3% of total selling price ($516)	15	21
Fixed		
Maintenance, 4% of fixed capital	32	44
Wages and salaries	5	7
Other fixed	6	8
Total	43	59

Capital-dependent		$/t SCP	$/t protein
Depreciation		82	114
Interest on loan		55	76
Dividend		38	53
	Total	175	243
	Total selling price	516	716

a/ 1,200 kWh for refrigeration; 1,400 kWh for rest, mainly compression.

BP process, 300,000 t/yr

Variable		$/t SCP	$/t protein
0.97 t paraffin at $340/t		330	569
0.05 t P_2O_5 at $500/t		25	43
0.14 t ammonia at $120/t		17	29
Other materials		15	26
1.3 t steam at $5/t		6	10
12.2 MMBtu gas at $1/MMBtu		12	20
3,300 kWh[a/] electricity at $0.0067/kWh		22	38
1,250 m^3 sea water at $0.0067/$m^3$		8	14
5 m^3 pure water at $0.18/$m^3$		1	2
Other services		1	2
	Total	437	753
Fixed			
Maintenance, 4% of fixed capital		33	57
Wages and salaries		5	9
Other fixed		6	10
	Total	44	76
Capital-dependent			
Depreciation		85	147
Interest on loan		58	100
Dividend		39	67
	Total	182	314
	Total selling price	663	1,143

a/ 1,200 kWh for refrigeration; 2,100 kWh for rest, mainly compression, stirring and centrifuges.

II. CONCLUSIONS AND RECOMMENDATIONS

A. Conclusions

The costs for the BP SCP (58% protein) and the ICI SCP (72% protein) may be compared as follows:

Item	$/t SCP		$/t protein	
	ICI	BP	ICI	BP
Feedstock	172	330	239	569
Electricity	17	22	23	38
Royalty	15	-	21	-
Capital-dependent	175	182	243	314
Rest	137	129	190	222
Total	516	663	716	1,143

The current price of soya meal (44% protein) is $306 per ton c.i.f. Kuwait, corresponding to $695 per ton protein, which is less than the cost of protein ($716/t) in ICI SCP calculated assuming 15% return on equity. The return would, in fact, have to be reduced to 9% to achieve equality.

It must be concluded that when measured against domestic prices, the project (as so far defined and on the assumptions made) is of uncertain viability. However, only 5,000 t/yr of the capacity of 300,000 t/yr will be sold domestically; the balance of 295,000 t/yr must be exported.

It has not been possible to estimate ex works prices for the export market because:

(a) The export markets have not been identified, although it is known that they will probably exclude Western Europe (licensor's restricted territory), the United States (soya producer) and other Gulf States (own production and small market). The market will thus probably be in Pakistan, India, South-east Asia and perhaps Indonesia and Australasia as well. There will certainly be adequate demand in this area as a whole to absorb 295,000 t/yr of SCP, but determination of the distribution of sales would require a market survey in the field which has been beyond the scope of this preliminary feasibility study;

(b) It has proved impossible to determine with any accuracy the freight costs from Kuwait to possible markets. This is partly because there are no quoted rates from Kuwait as there are not many exports other than oil and liquid oil products; and partly because SCP is a new product for which no rates exist, even in the inward direction. Rates quoted for similar products such as soya meal, fish-meal and poultry feed differ widely.

However, it would seem that the freight rate to the nearest likely market would be at least $40/t SCP ($56/t protein), and this will be also the amount by which the value of exports from Kuwait will be below the domestic value, if it is assumed that the c.i.f. price of the competing soya meal at the port of destination is the same as in Kuwait. A reduction of $40 per ton in the ex works price of SCP would make the project (as so far defined) unprofitable.

The cost of producing protein by the BP pr   is 70% higher than by the ICI process because of the high price of n-paraffin feedstock and the low protein content of the product. The BP process does not seem to be an economic possibility for Kuwait at the present time but it should be kept under review in case circumstances change; for instance, if there is a large change in the price of n-paraffin coupled with an improvement in process efficiency.

It may be asked what changes must take place in order to make it possible to produce protein economically by the ICI (or similar) process. It must first be noted that all estimates in this preliminary feasibility study are approximate and involve a number of untested assumptions. An actual production cost only 10% ($50/t SCP) below the estimate might be sufficient to ensure profitability in both domestic and export markets. Consideration should be given, perhaps in co-operation with the process owner and an engineering firm, to improving the accuracy of the estimate. Similarly, a 10% increase in the price of soya meal might also bring about profitability, and steps should, therefore, be taken to estimate furture prices. The following further possibilities exist:

(a) The project might receive official support in a combination of the following ways:

(i) Reduction of loan interest rate from 8% to 5% p.a. (which would achieve a reduction of $21 per ton SCP);

(ii) Reduction in the cost of electricity from 2 fil/kWh to 1 fil/kWh ($8/t reduction);

(iii) Reduction in the cost of gas from $1/MMBtu to $0.034/MMBtu (14 fil/1,000 ft^3), the standard price at Shuaiba ($11/t reduction).

The effect of these possible reductions upon the total cost of SCP is set out in more detail in annex III.

(b) Technical improvements (which all process owners are known to be seeking) may reduce feedstock consumption, perhaps by 10% ($17/t reduction);

(c) It may be possible to sell SCP at a price higher than that calculated from its protein content alone. If the purchaser takes account of other nutrients, then the value is found to be about 8% higher ($40/t). If the improved response of broilers and layers to diets containing SCP is also taken into account, then a still higher price may be obtained. It is certainly possible to obtain some of the enhanced value in Western Europe when dealing with technically advanced and knowledgeable feed manufacturers who are vertically integrated into broiler and egg production. It is not certain whether the extra value is realizable in the less sophisticated and more diffuse markets of developing Asia; this could only be determined by market research, which would probably demonstrate that a well organized and widespread technical service organization would be needed to convince producers of the value of SCP.

It would seem impracticable to seek reduction of cost by increase of scale above 300,000 t/yr. A reduction of $50/t SCP would need capital per ton-year to be reduced by 25% (taking into account both capital-dependent charges and maintenance requirements). This would require the plant size to be increased by about two and a half times to 750,000 t/yr. Such a large plant is not at present foreseen by the various process developers (who are very large firms) and should not be contemplated for Kuwait because of the technical and commercial risks involved.

As the world protein gap develops, the price of vegetable protein will rise. It is also likely that energy prices will also rise as hydrocarbon resources become exhausted. In any extension of this study, the future values of energy and soya meal should be estimated in order to determine the future viability of an SCP plant.

The summary of conclusions is as follows:

1. The manufacture of SCP in Kuwait is technically feasible. Refrigeration cooling would have to be employed at additional investment and running cost.

2. The market in Kuwait for SCP will be only 5,000 t/yr in 1981 and will increase only slowly thereafter.

3. SCP will be sold in competition with other animal feed protein supplements. The price of the principal protein supplement, soya meal, will determine the price obtainable for SCP.

4. Of the known technologies, only those using methanol feedstock (such as the ICI process) are likely to produoe SCP at a price competitive with soya meal.

5. The minimum economic size for a methanol-based SCP plant is 300,000 t/yr for which the investment cost would be $240 million. The investment for the associated methanol plant would be $120 million. A 300,000-t/yr plant is technically feasible and indeed one is likely to be built in Europe.

6. The cost (including remuneration of capital at commercial rates) of producing SCP from methanol in a 300,000-t/yr plant is approximately estimated to be somewhat greater than the maximum estimated f.o.b. price likely to be obtained in the export market, where nearly all the output of the plant would be sold. However, the difference (about 10%) is within the accuracy of the estimates so no final conclusion concerning the viability of the project can be drawn.

7. The cost estimate was made with conservative assumptions. A reduction of loan interest rate from the assumed 8% to 5%, of gas rate from $1 to $0.03/MMBtu, and of electricity rate from 2 fil/kWh to 1 fil/kWh would reduce the calculated cost of SCP by about 10%.

8. Current prices are used in the estimates. If, as the world protein gap develops, soya meal prices rise more quickly than energy and construction costs, the manufacture of SCP in Kuwait will certainly become profitable.

9. Although 300,000 t/yr is only a tiny fraction of the total amount of animal feed protein supplement that is traded each year, the problem of export marketing will have to receive careful attention before any SCP project goes ahead.

B. Recommendations

A preliminary estimate, of limited accuracy, has shown that at present costs SCP manufactured in Kuwait may or may not be able to compete profitably with soya meal (which SCP would partially replace in animal feed) at its present price. Profitability could probably be secured by the supply of utilities at favourable prices, or in the future when the price of soya meal is expected to rise.

Possible future actions are set out below:

1. The total investment needed for the SCP plant and its associated feedstock plant will be more than $300 million. Kuwait is already studying the possible construction of an aromatics plant and an ethylene plant, each of which will require a similar investment. It is suggested that the appropriate authorities in Kuwait decide the following:

(a) Will resources in Kuwait be sufficient to permit the simultaneous execution of more than one $300 million project?

(b) If not, what priority is to be given to a SCP project, and what then will be the possible commissioning date?

2. The preliminary feasibility study should perhaps be extended so as to determine the viability of the project with greater accuracy and using costs and prices appropriate to the possible commissioning date. The steps in this further study are detailed in annex IV. The major matters to be decided will be the method of export marketing and the export prices obtainable.

3. The successful realization of a major SCP project requires the collaboration of many institutions and of individuals of many different disciplines. If the priority given to an SCP project warrants it, it is suggested that the co-operation of these institutions and individuals be formally organized so as to secure maximum co-operation and effectiveness. Experience in other countries has shown that the best results are obtained from a two-tier committee system: (a) policy committee and (b) executive committee.

Policy committee. This is composed of ministers (or their alternates) and/or departmental heads representing the functions (in alphabetical order) of:

Agriculture
Commerce (especially foreign trade)
Finance
Health
Petroleum and petrochemicals
Planning
Technology (e.g. university)

The policy committee will meet three or four times a year to review the work of the executive committee and to take policy decisions concerning the SCP project.

Executive committee. The executive committee is a working group and indeed could be so called. It will comprise individuals with the skills and experience listed below:

Accountancy

Animal nutrition

Chemical engineering

Foreign trade

Higher education

Legal

Mechanical engineering (plant construction)

Medicine (public and industrial health)

Plant operation

Technology

The work of the executive committee will be directed by a chairman who has the natural and conferred authority to require any member of his committee to carry out a specified task or study and report the results to the committee for discussion by a stated date. Collectively, the executive committee will submit reports and recommendations through the chairman to the policy committee.

The executive committee will meet as required but probably at least once a month.

Some of the listed skills may be combined in a single individual. Some individuals, e.g. those recruited for their legal or medical qualifications, may not be needed at every meeting.

Both committees may be assisted as required by co-opted specialist advisers.

It is possible that some of the executive committee will have to travel abroad for discussions with process owners, traders and engineering firms and to visit institutions and operating SCP plants.

Annex I

SUPPLEMENTARY INFORMATION

A. Planning a study of the feasibility of manufacturing SCP

Before starting a study, it is necessary to ascertain the attitude of the Government to the proposed SCP plant.

The authorities of the state in which the SCP plant is to be built are likely to be involved at all stages of the study, particularly when the study has been commissioned by these authorities, when the plant is to be owned and operated by a government agency and when raw materials are to be supplied or product is to be distributed by the government. However, even when the Government is not involved in these ways, it is likely that close contact with the authorities will be required in many other directions.

It will, for instance, be necessary to determine the objectives of those who seek to build the plant. It may be intended to make the enterprise an export-oriented one in order to up-value local resources and earn needed foreign exchange. Alternatively, the plant may be required to supply product mainly to the domestic market in substitution of imports and to reduce dependence upon foreign sources of food for political and strategic reasons. In some cases the distribution system may be under government control and may in fact be the means by which government subsidies are injected into the feedstuff business. The Government may intend to erect tariff barriers in order to protect the new industry.

When considering the choice of technology, the authorities may express a wish to use either the so-called "high technology" which requires the construction of a large unit at a very high investment cost, which converts feedstock to SCP efficiently, but requires only a small labour force; or may choose instead "low technology" in which simple apparatus is used on a small scale requiring little investment but much labour. The Government may also wish to specify the raw materials to be used in the manufacture of SCP, for instance, it may be desired to conserve diminishing resources of liquid hydrocarbons and instead to use natural gas which is at present being flared and of which there are much bigger reserves.

Any feeding trials will be carried out using the 'target' animals to which the SCP will be fed. The selection of these animals will in many cases be a matter for the Agricultural Ministry of the state concerned: this Ministry will act within a framework of general government policy. In some territories it will be decided to maintain and expand existing intensive farming operations such as the production of broilers and the battery production of eggs. In other cases it may be decided to maintain traditional agricultural practices, for instance, SCP may be required for use in protein supplements to be fed throughout the winter to free-range ruminant animals.

Much has been done and written about the safety of SCP and it is inevitable that the health authorities of the state will concern themselves with this matter. Their views and requirements will have to be ascertained but, as is shown later, normally it should not be necessary for a state to undertake its own safety testing in respect of a product that is already sold in a developed country with the approval of that country's regulatory authority.

The selection of a site for the SCP plant may be influenced by government requirements. The authorities may be anxious to have the plant put up in a development area and may be prepared to give special subsidies to encourage such investment. The supply of certain scarce raw materials and services (for instance, water) may be allocated by the Government who can then in this way influence the location of plants consuming such materials and services. A government requirement that the consumption of water be limited might lead, for instance, to a decision to incorporate air coolers into the design of the SCP plant.

An investment decision will depend upon the prices, which may be under government control, at which raw materials and utilities are supplied to the SCP plant. The decision will also take account of the taxes to be levied upon the new industry by government and local authorities. The required selling price of the product will depend upon the interest rate at which the loan component of the investment can be borrowed, the loan/equity ratio, and the required return on the equity investment. These financial criteria will be fixed largely by local commercial custom but, when the Government itself is an investor, will be subject also largely to government decision, especially concerning the required level of profitability.

Plan and priorities

The work required to establish the feasibility of manufacturing SCP in a particular territory is shown in the table. For reasons discussed below, it is recommended that generally the different parts of the study be carried out in the order shown.

The steps shown in the table can be examined by their relative importance to any particular project, by their dependence one upon another, and by the expense of carrying out the step.

The relative importance of items will be different in different projects. For instance if it is intended to consider for adoption only fully developed technologies that have been demonstrated on the commercial scale for a satisfactory period, and to consider only products that are already freely sold for use in animal feeds, then it should be necessary to spend only a little time in the examination and selection of various technologies, and to spend little or no time in the conduct of animal feeding trials and in the determination of the safety of the product. All relevant information will already be in the possession of the process owners and its reliability will have been established by the demonstrated performance of an existing plant, by the confidence of customers in the product, and the attitude of the regulatory authorities in the countries in which the product is sold. On the other hand, if a relatively untried technology is to be considered, then much effort would have to be devoted to a detailed examination of its merits and an independent determination of the nutritive and toxicological properties of the product.

Plan for a feasibility study of manufacturing SCP

1. Commercial

   (a) Market: nature and size

   (b) Price obtainable

2. Technology

   (a) Selection

   (b) Licence terms and fees

   (c) Adaptation to locality
   (d) Local resources of technical manpower and training requirements

3. Animal feeding trials

4. Safety of the product

5. Engineering

   (a) Site selection
   (b) Design decisions
   (c) Scheme design
   (d) Investment cost

6. Investment decision

   (a) Raw materials and utilities: supply and price
   (b) Total production cost: profitability
   (c) Investment proposal

The nature of the market investigation will depend largely upon whether the product is to be sold locally or whether most of it is to be exported. The market investigation has for its objective the determination of likely volume and likely price and if the sales are likely to be concentrated in one particular market, then relatively small attention need be given to the alternative market which will demand only a small volume and will contribute little to the calculation of average price realization. The determination of volume and price in a domestic market, although time-consuming, can be carried out by established methods and is likely to yield a reliable estimate. On the other hand, the study of an export market is more difficult, more complicated and, normally, is subject to much greater uncertainties. As is well known, a project with a substantial domestic market is likely to be more stable and its viability is likely to be more easily demonstrated, than a project which is export-oriented.

Turning now to the logical order in which information is to be obtained, much depends upon the use in some stages of the investigation of information obtained in others. It is noted first the obvious point that the final investment decision cannot be taken until all the other stages of the study have been completed.

It is noted also that design decisions, and a scheme design leading to the determination of an investment cost, cannot be undertaken until the technology has been selected. It is seen also that the source of certain raw materials (including that of the substrate) and their prices also cannot be determined until the technology is known.

The determination of investment cost, which involves the preparation of a scheme design, is extremely expensive and time-consuming and will involve the participation of an engineering firm. The considerable expenditure should not be undertaken until earlier stages of the investigation have shown that it will be worthwhile. If, for instance, no satisfactory market for the output of an SCP plant can be identified, then it is useless to embark upon the investment study or, indeed, upon the selection of technology, the undertaking of feeding trials, and the provisional safety clearance of the product.

The items in the table are listed in the order in which they should be done in a study of the feasibility of SCP manufacture in a case where it is intended only to consider fully developed technologies already in commercial use. However, in some cases it will be noted that information from a later stage may be needed to complete an earlier stage; for instance, the price obtainable, determined in the course of the commercial study, should at once be compared with the production cost to be determined in the course of arriving at an investment decision. This interaction, however, does not present any particular difficulty so long as only established technologies are considered. For these, it will be a relatively simple matter to arrive at an approximate production cost using confirmed data supplied by the process owner and adapted to local conditions. The accuracy of this approximate production cost estimate should be good enough to establish a prima facie case for or against the continuation of the study after the market survey has been completed.

When the SCP products are already being sold in developed countries, it should normally be unnecessary to carry out safety testing in a developing country in which it is proposed to introduce the technology. However, examination by the local health authorities of the test results carried out elsewhere, and the nature of the approvals given by foreign regulatory authorities may be required.

Some animal feeding trials using target species may be needed in order to establish whether there are any differences between the responses obtained under different climatic conditions and using different feed components from those employed in the developed countries in which the product is already sold.

Although the order of items in the table is a logical one, and indicates a sequence of investigations, in practice many of the investigations will be carried out simultaneously although to different target completion dates. For instance, it may be possible at an earlier date to make inquiries about the source and price of raw materials and utilities although firm figures will not be needed until the final stage involving an investment decision is undertaken.

B. Questionnaire

Policy and general

1. Do the Kuwaiti authorities want to make SCP for domestic consumption, for export, or both?

2. What will be the ownership of the SCP plant? Will the investment be by:

   (a) State or State agency
   (b) Private Kuwaiti interests
   (c) Foreign company
   (d) A combination of above

3. What investment conditions would apply to 2 (a) and 2 (b) above?

   (a) Loan/equity ratio
   (b) Loan interest and repayment terms
   (c) Tax on profits
   (d) Required return on equity investment

4. What laws apply to foreign investment (2 (c) above)?

5. What subsidies or other state encouragement might be available for an SCP plant?

   (a) Investment grant
   (b) Soft loan

(c) Infrastructure provided at no charge to the project
(d) Accelerated depreciation
(e) Tax holiday or tax remission
(f) Revenue subsidy
(g) Low cost feedstock
(h) Other

6. What is the preferred feedstock, and why?

7. When is the plant required?

8. Is only commercially proven SCP technology acceptable?

Market

1. Population, GNP per person, dietary habits, and trends.

2. Meat imports by type, volume and value: present figures and future trends.

3. Protein feed imports by type, volume, unit cost, and value: present figures and future trends.

4. Domestic production of red meat:

(a) Type, volume and value
(b) Feed and methods used
(c) Organisation and marketing

5. Domestic production of eggs, chickens and other white meat:

(a) Type, volume and value
(b) Feed used: nature and whether domestically produced or imported
(c) Organisation and marketing
(d) Results achieved: growth rate, feed conversion efficiency etc.
(e) Any international affiliations

6. Feed compounding industry:

(a) Size, organisation
(b) Raw materials and formulation criteria
(c) Any international affiliations

7. Exports:

(a) Traditional and favoured trading partners
(b) Payment conditions, e.g. is soft currency or barter acceptable
(c) Port facilities and costs
(d) Overland routes and costs

Technology and engineering

1. What sites are to be considered? For each possible site, what facilities are or will be available?

(a) Prepared ground
(b) Roads, railways
(c) Electricity
(d) Water: drinking, brackish, piped sea water
(e) Gas
(f) Feedstock storage
(g) Access to port
(h) Offices, laboratories
(j) Site amenities, e.g. canteen, ambulance room
(k) Housing
(l) Public amenities, e.g. schools, hospitals

2. Wet and dry bulb temperatures and sea-water temperatures during the year. Duration of high temperature periods.

3. Port facilities and transport to site: costs; maximum size equipment that can be handled, by weight and by dimensions.

4. Local availability of construction raw materials, e.g. steel, cement.

5. Local manufacturing and fabrication facilities.

6. Earthquake classification.

7. Availability and price of feedstocks: natural gas, methanol and normal paraffins.

8. Local higher education and laboratory and research facilities especially in microbiology and animal nutrition: availability of technically trained manpower.

9. Plant construction costs in relation to those in Western Europe or the United States.

10. Typical plant construction times.

11. Engineering firms with experience in Kuwait: favoured contractors.

Cost data[a]

1. Unit costs of materials:

   (a) Major: Natural gas
   Methanol
   n-paraffins
   Ammonia
   Phosphoric acid: (i) Furnace grade
   (ii) Solvent-extracted wet process

   (b) Minor: Sodium hydroxide (47% solution)
   Magnesium sulphate (calcined 98%)
   Potassium sulphate (50% K_2O, i.e. 92.6% K_2SO_4)
   Sodium sulphate (95%)
   Calcium nitrate
   Ferric sulphate (40% solution)
   Soya oil
   Tallow

2. Unit costs of services:

   (a) Steam (low pressure)
   (b) Electricity
   (c) Natural gas
   (d) Water: (i) Drinking
   (ii) Piped sea water
   (iii) Other available water

3. Labour rates (with benefits in each case):

   (a) Unskilled workers
   (b) Skilled workers
   (c) Technicians and skilled commercial staff
   (d) Graduates and other managers

4. Taxes:

   (a) State and local taxes: how and when levied
   (b) Special taxes applicable only to foreign investors
   (c) Rate of depreciation allowable against profit for tax purposes

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a/ Materials and services for the ICI and BP processes are listed. Some alternative materials may be needed for other processes.

C. Feed requirement for meat production

In Kuwait, a lamb is slaughtered at a weight of about 52 kg to produce a carcase of 25 kg. At all stages of growth, the animal requires 0.23 kg of crude protein in its feed for each kg of weight increase. Therefore, at 52 kg weight, 12 kg of protein will have been used.

Protein is also needed for the maintenance of the breeding ewes. This is normally 0.11 kg/day but increases to 0.27 kg/day during pregnancy and to 0.50 kg/day during lactation.

One sheep will, in the proposed scheme for meat production, produce 1.5 lambs per year. Annual protein requirements will be approximately as follows:

	Protein (kg)
Maintenance of 1 ewe at (say) 0.3 kg/day	109
Production of 1.5 lambs at 12 kg total	18
	127

It is proposed to have a prototype sheep farm with 25,000 breeding ewes which (at the assumed reproduction rate) will produce 37,500 lambs per year. The total protein requirement will then be 25,000 x 0.127 = 3,175 t/yr. Much of this protein will be contained in grain which forms the bulk of the diet: the rest is normally added as vegetable protein meal part of which could be replaced with SCP. Total feed will be about 20,000 t/yr. It is considered that SCP could be added to form about 5% in diet, i.e. 1,000 t/yr.

The production of 37,500 lambs (1,950 t) for meat, from 25,000 ewes will yield 37,500 x 0.025 = 937 t of meat carcasses. The import of meat into Kuwait in 1975 was 26,000 t of live animals and 30,000 t of meat. The proposed prototype farm will evidently provide only a very small fraction of Kuwait's meat requirements, and these will be thus considerable scope for further increase in meat production and potential consumption of SCP.

D. Protein-Calorie Advisory Group (PAG) of the United Nations System: Summary a/ of the symposium b/ on single-cell proteins for animal feeding

The development and use of single-cell proteins (SCP) has been going on for many decades. But, apart from wartime situations, it is only in the last decade that it has taken on major new impetus - with the use of hydrocarbon substrates coming into prominence.

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a/ By Professor N. S. Scrimshaw (Chairman), PAG *ad hoc* Working Group Single Cell Proteins.

b/ Held in Brussels, Belgium, 29-30 March 1976.

It has been pointed out that Western Europe meets only 20% of its feed protein needs and, according to Professor J. C. Senez of France's Centre National de la Recherche Scientifique, that it is importing 8.2 million t/yr of protein concentrates, mainly soya bean meal from the United States, at a cost of $4,000 million. Any import substitution which is economically viable would be desirable. In addition the USSR has a major need for protein concentrates for animal feeding.

Secondly, world population has passed 4,000 million and is expected to double soon after the end of the century. Although much can be done to increase agricultural yields and there is still some additional agricultural land, there will be a growing need for food which can be obtained without direct dependence on such land. So, both an immediate need, and a growing future one, is waiting to be filled if safe, nutritious and economic single-cell protein products are available.

It was clear from the presentations at the Symposium that there are three products in Western Europe - Toprina, Pruteen and Liquipron - which have undergone very extensive testing in laboratory and farm animals and for which large scale production plans exist. For Toprina and Liquipron, which are both yeasts grown on normal paraffins, by British Petroleum and Liquichimics respectively, 100,000-t/yr plants have been constructed in Italy and are waiting on government approval. In addition, Toprina production on a normal paraffin substrate (contained in gas oil) has proceeded in an 18,000-t/yr plant at Lavera, France.

Production continues in a 4,000-t/yr plant in Grangemouth, Scotland, using a normal alkane substrate. In four years of commercial sales for calf, poultry and swine feeding the material has been well accepted and no problems have been encountered.

For Pruteen, a bacterial product grown by Imperial Chemical Industries on methanol, future plans depend on economic trends.

In addition, Shell is investigating the use of methane as a substrate employing multiple organisms.

In the USSR, intensive research has led to the identification of efficient organisms and extensive analytical and biological evidence of their safety for animal feeding has been obtained. The Symposium was informed that a plant capable of producing at least 100,000 t/yr was completed in 1973 and additional plants of this size were completed in 1974 and 1975. Several additional large plants are planned.

As to toxicologioal testing of these materials, the Protein-Calorie Advisory Group of the United Nations System (PAG), whioh sponsored the Symposium, developed guidelines for the nutritional and safety evaluation of new protein sources for human feeding in 1972 and a separate guideline for the evaluation of SCP for animal feeding was issued in 1975. A complementary set of recommendations relating to SCP for animal feeding has been prepared by International Union of Pure and Applied Chemistry (IUPAC).

As summarized by Dr. B. L. Oser of Bernard L. Oser Associates Inc., and a consultant to the United Nations, these guidelines call for extensive analyses to ensure appropriately low levels or absence of heavy metals and other undesirable substances. Also required are tests of the microbiological stability of the organism; freedom from microbiological contamination; adequate nutritional value and acceptable freedom from toxicity - as determined by short and longterm tests using experimental and target animals - plus multigeneration studies; special tests for teratological or mutagenic properties and practical feeding experiments.

Dr. A. P. de Groot (of Holland's Central Institute for Nutrition and Food Research) and Dr. D. Stringer (of ICI) presented an impressive array of biological results from rats, mice, quail, pigs, chickens, calves, monkeys and other animals attesting to the safety of the SCP materials evaluated. Dr. de Groot also spoke of SCP feeding studies on 19 generations of rat, with reproductive studies within each generation, and on 28 generations of quail.

The PAG guidelines have been followed with extraordinary care, diligence and expense. No food or feed product on the market today has been so thoroughly tested for safety as those discussed at the meeting.

In addition to the general toxicological testing, a number of special issues were raised.

Since the extensive studies of normal growth, reproduction, life span, performance trials and of substrate purity have not been enough to satisfy all doubters, attention was focused on four specific issues.

The first of these was the matter of strain stability. Could there be mutations of the organisms involved which might pose a health hazard? It was noted that the guidelines call for detailed control procedures, both morphological, chemical and biochemical, to detect such change if it occurs and thus ensure safety.

Moreover, the required control procedures of good manufacturing practice are such that, in the remote chance that such a change occurs, the material could be stopped from reaching the market. It was noted that in the years of experience with the organisms described at the meeting, no such mutation had been observed.

Furthermore, from a production point of view, the most likely consequence of a mutation would be an alteration in productivity and there is as much concern for maintaining strain stability for high productivity as for safety - the two go together. Periodic biological tests for toxity are also done.

The second issue relates to the occurence of fatty acids with an uneven number of carbon atoms in the chain. Elegant studies by Dr. S. Garattini of Italy's Istituto di Richerche Farmacologiche "Mario Negri" have shown that these are transformed into metabolic products as are the more common even-numbered fatty acids; are available for the stress response; and are unassociated with any changes in brain, heart, liver, blood platelets and a series of other tissues.

Moreover, there are many earlier studies that have shown these uneven numbered carbon-chain fatty acids to be constituents in many other foods, and to be metabolized by way of physiologically normal pathways. They are normal constituents of many other foods.

. C.A. Shacklady, of BP Proteins Limited, provided some interesting supplementary evidence when he reported that such fatty acids had no detectable effect on mouse peritoneal macrophages, on rat liver mitochondria respiration and no mutagenic activity with five different strains of test organism.

Third is the question of residual normal paraffin, that is saturated linear chains of carbon atoms, particularly in the range of C18 to C33. Body fat composition is responsive to dietary fat - a fact known to all animal feeders. It is not appropriate to speak of these changes in fatty acid composition with diet as residues, since they are transformed into metabolic products as are the more common even numbered fatty acids according to the nature of the fat in the diet and according to physiological demand.

Micro-organisms and plants contain hydrocarbons of various types resulting from biosynthesis. In the case of SCP derived from alkane substrates, the level of paraffins which they contain is generally in the range of 1 part in 1,000 (0.1%) and 1 part of 200 (0.5%) of the total weight and never above 0.5%. It is not surprising, therefore, to find a proportion of these paraffins in the fat of some species of animals which have been fed diets containing this type of SCP.

The paraffins in the fat of animals fed yeast grown on normal paraffin are within the limits of normal variation. In fact, much higher levels have been found in the fat of cattle fed entirely on grass.

Although, for many years, linear alkanes were regarded as being biologically inert, it is now known that if absorbed they can be oxidized to the corresponding fatty acids by enzyme systems existing in the animal body. This is more readily achieved with the liquid than the solid alkanes, that is to say with alkanes of the carbon chain length residual in the SCP grown on hydrocarbons.

Such evidence as is now available indicates that the level and nature of the residual paraffins in SCP present no hazard to the health of animals fed on these materials, provided a feedstock of adequate purity is used in the cultivation of the biomass. Neither is there any evidence of hazard to the health of consumers of products from these animals resulting from the presence of such paraffins as may have been transferred to these products from the SCP. Indeed, in some cases, this is below the level of paraffins found in the fat of animals which have been fed on diets containing no SCP.

Recent studies have demonstrated that the paraffins extracted from alkane-grown SCP have no deleterious effect on the viability and respiratory function of sub-cellular organelles nor do they have any mutagenic effect upon the strains of S. typhimurium, which have been developed as test organisms for this purpose. These confirm the long term feeding and multiple generation studies on the intact animal which have already been reported to the PAG.

The use of n-paraffins in a number of staple food preparations is allowed in most countries. The level of food grade mineral oil which is permitted in the processing of foods such as bread, rice, meat left residues many times higher than has been found in the fat of animals fed on SCP grown on alkanes and no harmful effects have been reported as resulting from this widespread and long standing practice.

The fourth special topic is a false issue. Since benzepyrene and other aromatic hydrocarbons can be induced in crude petroleum by high temperature cracking, the use of a petroleum-derived substrate brings with it the spectre of possible carcinogenesis. However, as Dr. Oser pointed out, the feedstocks used for SCP production are free of such substances, as judged by the most sensitive gas-chromatographic analysis available; that is they have less than one part per 1,000 million and perhaps none.

The question then arises: could the organism concentrate undetectable traces of such materials, again not detected in the SCP products themselves, and could these undetectable levels be carcinogenic? The answer is that, in experimental studies with direct feeding of these aromatic hydrocarbons, it takes far above one part per 1,000 million to begin to have detectable carcinogenic effects. Moreover, no carcinogenic effects turn up in multi-generation studies and in life-time studies, where these materials have been fed at levels well above those which would be used in normal commercial feeding. These studies have been done in a number of different countries.

Could these materials somehow get into the fat of animals fed SCP? Again, not according to the most sensitive chemical analyses available. However, traces of these aromatic hydrocarbons do get into our environment in many ways, including traces in some feeds and food supplies, and turn up in trace amounts from other sources. There is no indication that SCP prepared in the ways discussed would add to that hazard.

It can thus be concluded from the Symposium discussions that there is no current scientific ground for objecting to SCP as animal or human food on the basis of any of these four special issues. Moreover, there is no evidence that more work is required to settle any of these issues for the materials described, although further research will be required as each new SCP product is proposed for animal feeding.

An additional special point strongly emphasized in the PAG guidelines was mentioned by Professor L. Rey of Nestle Alimentana. That is that no set of animal tests can be a substitute for cautious and systematic tolerance studies in human subjects when any new SCP material is intended for direct feeding as is true for any new protein source. This is because there can be allergic reactions in human subjects which cannot be detected - at least up to this point - in experimental animals. There must also be taste and functional characteristics not necessary in a material for animal feeds.

The next point deals with government regulations. Governments must have, and most do have, reasonable procedures for processing an application, for evaluating the scientific data or having it evaluated by competent advisory groups, and for prompt and clear decisions, either affirmative or indicating such additional data as may be required. The United Kingdom has a slight variant of this in which more responsibility is placed on the producer. In any event there is a requirement for strict internal laboratory controls on the part of the industrial concern and also for external controls by the appropriate government agency. The PAG and IUPAC guidelines are intended to facilitate this process for both government and industry.

In evaluating scientific data the PAG looks critically at all data, regardless of source. Excellent scientific contributions to these subjects have come from universities, from research institutes, from government laboratories and industrial research laboratories. The criterion is the quality of the scientific work, not where it is done. On the basis of the data which have been obtained, Toprina can now be sold in the United Kingdom, France, Federal Republic of Germany, Holland, Belgium, Denmark, Luxembourg, Switzerland, Spain and Portugal as animal feed, without restriction other than normal quality controls. In the USSR, the SCP produced on normal paraffins (designated BVK), is used at a level of several hundred thousand tons per year. The problem comes when factors other than scientific considerations, and the national and public health interest, intervene to mislead or arouse public opinion or to delay or block decisions - this the PAG Working Group can only deplore.

No blanket statement should be made about SCP because it is a generic term covering many different possible organisms, substrates and processes. Only certain organisms, substrates and processes will prove suitable for animal or human feeding. It can be stated, however, that man's experience with similar products - brewers' and bakers yeast - over centuries, and with Candida utilis grown on various carbohydrate substrates - establishes the principle of safe use of selected SCP products.

Now it has been demonstrated that selected yeasts and bacteria grown on purified hydrocarbon fractions such as normal alkanes and methanol can also be safe and nutritious for animal feeding and the resulting animal product used in human diet. It can be concluded that as far as these particular materials are concerned there are no nutritional or toxicological barriers to their commercial development. Their future should depend entirely on economic viability and the public interest.

E. Utility costs at Shuaiba

Utility	Unit	Fil	$
Land rental[a]	m^2 p.a.	75	0.25
Gas	m^3	0.49	
	MMBtu[b]		0.0345
Sea water	m^3	1.99	0.0067
Electricity[c]	kWh	1	0.0033
Fresh water	1,000 imperial gallons	250	
	m^3		0.0018

a/ The land rental in the case of a 300,000 t/yr SCP plant would probably be less than $0.20/t and has been ignored in all calculations.

b/ On the advice of the Ministry of Oil, a value of $1/MMBtu has been used in all calculations to reflect the possible future value when gas is no longer in surplus.

c/ This rate of 1 fil/kWh applies only in the case of large consumers and after government consent has been obtained. The normal rate is 2 fil/kWh ($0.0067/kWh) and this figure has been used in the cost calculations.

F. Refrigeration

Visits were made to the London offices of two firms of industrial refrigeration engineers: Carlyle Air Conditioning Co. Ltd (subsidiary of Carrier, United States) and York Marketing (division of Borg-Warner, United States).

Each will supply standard refrigeration sets to produce chilled water for process cooling; heat removal would, in the case of Kuwait, be by sea water. The biggest standard set has a cooling capacity of 37,500 tcal/h. The more detailed Carlyle data are:

Heat removed	37,500 tcal/h
Refrigeration compressor power	8,900 BHP
Equivalent heat	5,710 tcal/h
Total heat removed by sea water	43,210 tcal/h
Electric driver power	7,380 kW
Temperature rise of sea water	7°C
Sea-water rate	6,170 m^3/h

Sea-water inlet temperature (design)	30°C
Chilled water outlet temperature	16°C
Chilled water return temperature	28°C

The normal maximum sea-water temperature at Shuaiba is 33°C (sometimes peaking to 35°C). At 33°C, with the same power input, the chilled water temperatures would rise to 19° ⟶ 31°C. The standard ICI fermenter cooler is designed for temperatures of 20° ⟶ 34°C, so no change of cooler design is needed.

The cooling requirements of an SCP plant are, of course, calculated in detail during the design stage. For purposes of approximate estimating, the cooling requirements may be related to heat inputs (with an allowance for heat losses by radiation and as sensible heat in effluent streams). For the ICI process, after allowing for losses, they are approximately:

	tcal/t SCP
Electricity: 1,420 kWh	1,100
Steam: 1.28 t	830
Fuel: 12.2 MMBtu	2,800
Heat of fermentation	5,270
	10,000

Normally this heat is removed in a circulating cooling water system using an evaporative cooling tower requiring a make-up of about 19 m^3/t of clean water. In Kuwait, it will be necessary to remove heat as follows:

The steam heat and the heat of refrigeration by refrigerated chilled water: 5,270 + 830	6,100
The heat of compression, corresponding to the electrical input, in a clean water system in which part (say half) of the heat is removed by exchange by sea water and the rest by evaporation	1,100
The heat from fuel used for drying in a sea water cooled heat exchanger in the effluent gases	2,800
	10,000

This very approximate treatment leads to a calculated value of 7,036 tcal/t (including part of the heat added by the power input) to be removed by sea water in the refrigeration set; 2,800 tcal/h by exchange with sea water in the drier stack, and 550 tcal/h in the compression system. The residual amount of evaporative cooling will need only about 1 m^3/t clean water make-up.

Other clean water requirements on the plant are 2.6 m^3/t.

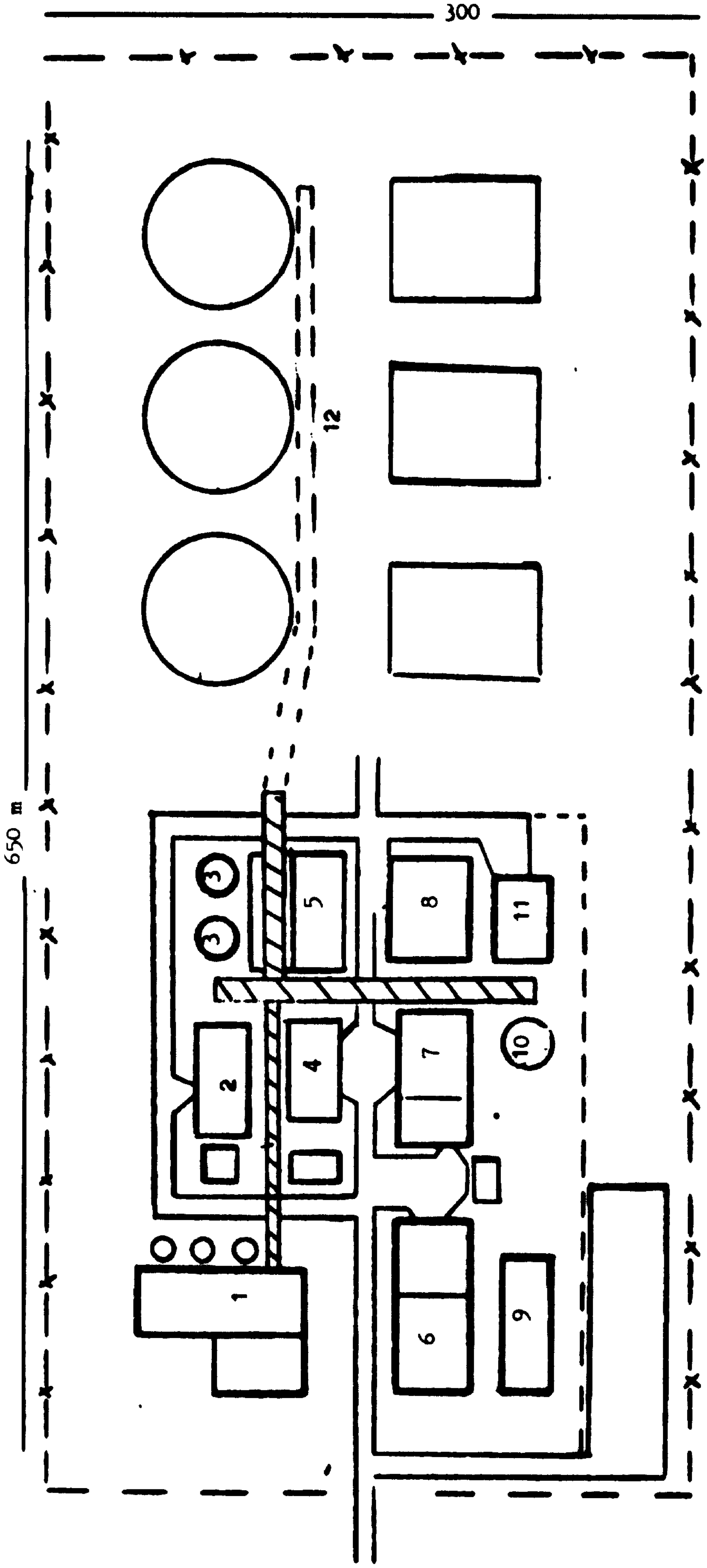
The suppliers state the purchase price of a 37,500-tcal/h refrigeration set (with electric motor) to be:

Carlyle	$1,215,300
York (£1.4 million):	$2,380,000

A figure of $2 million has been assumed. ICI estimates the installation cost (with connections) of these skid-mounted units to be 35% of cost. The total installed price (in Europe) is thus $2.7 million per set.

Six refrigeration sets will be needed for a 300,000-t/yr plant.

G. Layout of a 300,000-t/yr SCP plant

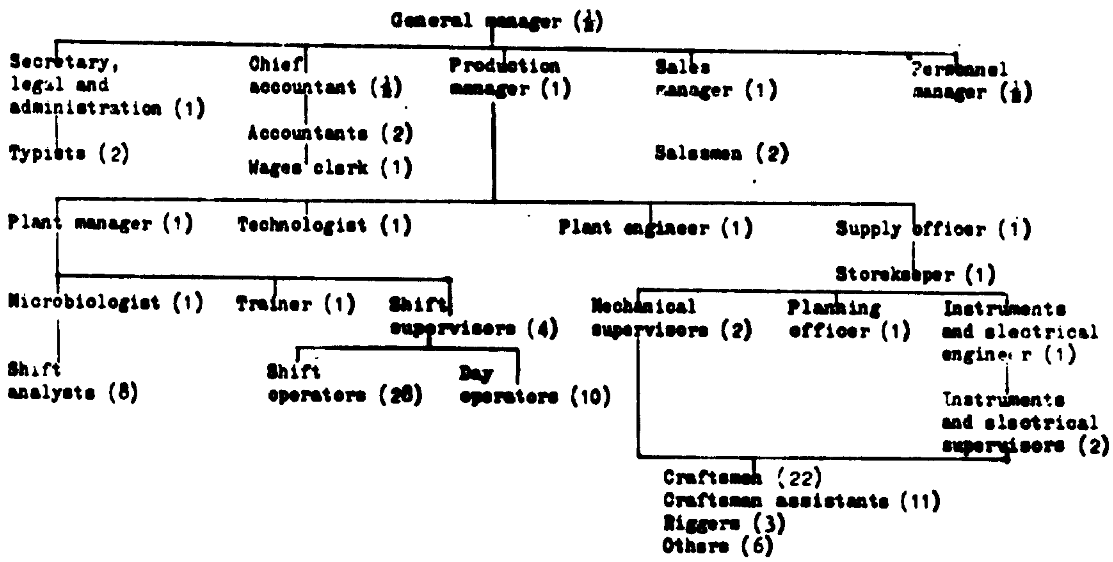


1. Finished Product Store
2. Drying plant
3. Fermenter
4. Control room and labs
5. Separation
6. Workshops
7. Raw material store
8. Compressor
9. Offices
10. Dump tank
11. Effluent treatment
12. Cooling plant

H. Plant manning and cost

The table shows the manning of a European SCP plant built on the same site as the associated feedstock plant and sharing certain staff, for instance the general manager.

Manning table



Total: 116½

Information about the pay of Kuwaiti staff and workers is available. The personnel in the table have been brought within the Kuwaiti classification and the total salary and wages bill calculated as follows:

Kuwaiti classification	Personnel in manning table	Number of persons	Salaries and wages (KD/month)	Total (KD/month)
General manager	General manager	½	760	380
Manager	Secretary (admin.)	1		
	Chief accountant	½		
	Production manager	1		
	Sales manager	1		
	Personnel manager	½		
		4	550	2,200
Engineer	Accountant	2		
	Salesman	2		
	Plant manager	1		
	Technologist	1		
	Plant engineer	1		
	Supply officer	1		
	Microbiologist	1		
	Instruments and electrical engineer	1		
		10	400	4,000

Foreman	Trainer	1		
	Shift supervisor	4		
	Mechanical supervisor	2		
	Planning officer	1		
	Instruments/ electrical supervisor	2		
		10	200	2,000
Secretary	Wages clerk	1	140	140
Typist	Typist	2	110	220
Skilled	Shift analyst	8		
	Craftsman	22		
		30	135	4,050
Semi-skilled	Shift operator	28		
	Day operator	10		
	Rigger	3		
		41	95	3,895
Unskilled	Craftsman assistants	1		
	Others	6		
		17	75	1,275
Storekeeper	Storekeeper	1	125	125
	Total	116½		18,285

Salaries and wages		KD 18,285 per month
Add 10% for benefits		KD 20,113 per month
Annual salaries and wages		KD 241,362 per year
	i.e.	$796,495 per year
	say	$800,000 per year

Petroleum Industries Corporation advises that the bill calculated in this way should be increased by 50% to reflect the higher manning level customary in a Kuwaiti plant and the employment of expatriates at high salaries.

The manning table relates to a 50,000-t/yr plant. It is arbitrarily increased by 20% to allow for the small additional manning needed by a 300,000-t/yr plant. The calculated wages bill is then:

(800,000 x 1.5) x 1.2 = $1,440,000 per year

Annex II

VISIT REPORTS

A. Policy and general

1. Director of Foreign Trade, Ministry of Commerce and Industry

Mr. Bader Abdullatif Abdul-Rahim (Director of Foreign Trade, Ministry of Commerce and Industry).

The meeting had been requested in view of the possibility of sales of SCP to soft currency areas such as the Eastern European countries and India.

Mr. Abdul-Rahim said that Kuwaiti foreign trade was normally carried out in hard currency. He knows of no barter deals; if such a deal were proposed it would have to be approved specially by the Government.

Mr. Abdul-Rahim supplied comprehensive statistics on Kuwaiti foreign trade.

There are no traditional or favoured trading partners. Some countries (e.g., Japan) are major importers of Kuwaiti oil and major suppliers of manufactured goods, both light (cameras, radios) and heavy (machinery, structural steel).

There is an agreement between Kuwait and the Council for Mutual Economic Assistance (CMEA). There are significant exports of agricultural and dairy products from CMEA to Kuwait.

Mr. Abdul-Rahim said that trade was carried by road between Kuwait on the one hand and Iraq, Turkey and Saudi Arabia on the other. In the latter case, road transport was more expensive than sea transport but was used to circumvent port congestion in Saudi Arabia.

2. Ministry of Planning

Mr. Riad Ali
Dr. Khalif (geologist)

Mr. Ali confirmed that Kuwait would welcome a new source of protein. Fish-meal was no longer available because of oil pollution in the Gulf.

There was a discussion about possible regional co-operation in the production of SCP. Dr. Khalif thought that this would be difficult to achieve.

3. Ministry of Oil

Mr. Abdulla Abdo-al-Noor

Mr. Jassem Haji

The Ministry representatives advised that the selection of an SCP process should be based primarily on economics. If the costs of a methanol-based process were about the same as those of a paraffin-based process, then the paraffin route should be chosen.

Gas, all of which was associated, was expected to be no longer in surplus in the future, and some power stations at present fired with gas might be changed over to residual oil. The Ministry recommended that for future projects gas be valued at $1/MMBtu.

4. Kuwait National Petroleum Co.

Mr. Abdulmalik Al-Gharaballi

In reply to a question about the preferred feedstock for an SCP plant, Mr. Al-Gharaballi said that there were no fractions in surplus; all fractions were sold at world market prices. The quantity of gas (all of which was associated) would diminish with the commissioning of the new liquefied petroleum gas (LPG) plant the product of which was for export.

Sea water is normally used for cooling by removing some of the heat from a circulating clean water system by heat exchange with the hot water before it enters the cooling tower. Direct sea-water cooling was not used. Air cooling, followed by trim cooling, was extensively used.

Mr. Al-Gharaballi was told that the area required for a 300,000-t/yr SCP plant was roughly estimated to be 180,000 m^2 (18 ha).

5. Industrial Bank of Kuwait

Mr. Vidkunn Hveding

Mr. Bassam Aburdene

Mr. Hveding had done a study of five joint ventures in Kuwait. All ventures had worked satisfactorily, but all were for the domestic market only; it was recognized that an export-oriented venture would have special problems that might impose additional strains.

The Chairman of PIC had told Mr. Hveding that:

(a) He was in general opposed to joint ventures in the petrochemioal field;

(b) He would resist provisions in joint venture agreements which, although not contrary to Kuwaiti law, would permit a foreign minority shareholder to exercise control not reflected by their shareholding; for instance, a provision that certain decisions must be taken by a two-thirds majority of the Board when the minority shareholding is more than one-third.

Mr. Hveding pointed out that if export marketing were undertaken by the foreign licensor and joint venture partner, there would be difficulties if the partnership were dissolved by the Kuwaiti interest buying out the foreign interest because the enterprise would then be left without a marketing organization.

B. Market

6. International feed commodity dealers in London

Visits were made to:

Tradax (part of the Cargill Group), Kempson House, 35-37 Camomile St., London EC3, telephone 01-283 5272. Mr. J. Cridlan

Continental (Europe) Ltd (part of the Continental Grain groups), P and O Building, 122-133 Leadenhall St., London EC3, telephone 01-283 4222 Mr. W. S. Biggs and Mr. K Hairs

Bunge and Co. Ltd (subsidiary of Societe Anonyme Bunge, Antwerp, Belgium), Bunge House, 71 St. Mary Axe, London EC3, telephone 01.283 3429. Mr. Paul Frain

All the meetings were oonducted similarly:

1. The expert explained that the possibility of building an SCP plant in Kuwait was being studied. Among other things, a reoommendation had to be made about the plant capacity. The small population of Kuwait would be able to consume only a small tonnage, which would probably be less than the minimum economic size of plant. Most of the output of the plant would have to be exported, and the possible level of exports might determine the ohoioe of plant capacity.

2. Limitations of export territory would probably be imposed by the prooess licensor: for instance ICI and BP might exclude Western Europe, and Japanese licensors might exclude Japan and other parts of Eastern Asia.

3. There would probably ultimately be several SCP plants in the oil-producing countries of the Middle East. Kuwait would be unable to export to other Middle East countries with such plants.

4. Public concern had been expressed about the safety of SCP and most governments would permit the sale only of approved products. Process licensors were concerned mainly with obtaining government approvals only in those territories where their own manufacture would be sold, e.g. in Western Europe in the case of ICI and BP, or in Japan in the case of Japanese processes. However, it seemed possible that governments outside these territories might accept approvals already given, for instance by the Federal Republic of Germany, French or Japanese Governments. (It is not necessary to get approval for the sale of SCP in the United Kingdom).

All the firms visited expressed considerable interest in the suggestion that they should handle the export surplus. Tradax and Continental did not regard the possible exclusion of the Western European market as a great obstacle: the amount of SCP to be sold was very small in comparison with the total quantity of protein supplements already traded and there should be no difficulty in finding buyers outside Western Europe. Bunge was somewhat more concerned about the possible exclusion of Western Europe.

Tradax and Continental said that they would propose that SCP be bought by them from the producers at a price related by formula to the price of soya meal, grain energy, certain amino-acids and other nutrients. Bunge thought other pricing arrangements might be possible. The buying price would also reflect the cost of freight to markets. Agency selling was neither proposed nor discussed.

The expert said that arrangements for selling the export surplus would have to be made in advance of a decision to build a plant, the capacity of which would be determined by the export sales volume to be achieved. All the firms visited said they would immediately get in touch with their principals in order that the proposals be further considered and in order that channels for further discussions and negotiations could be arranged. (In the case of Tradax, future contacts would probably be with the Cargill headquarters in Geneva.) Before such channels were nominated, communications would continue to be routed through the London offices already visited.

The expert asked the firms to consider annual export tonnages in the range 50,000-300,000 tons. None of the firms commented upon these figures as being too small or too big for consideration.

Information about the properties of SCP was left with the firms.

7. Possible exchange trading of meat for SCP between Kuwait and Bulgaria

A meeting was held with Mr. S. Mishev and Mr. M. Bozarov, Assistant Commercial Counsellors, Bulgarian Embassy in London at 104 Lancaster Gate, London W2 3NT.

The expert noted that in the past the Bulgarian Embassy in London, various Bulgarian Trade Missions, and the authorities in Bulgaria had expressed interest in the possible production of SCP in their country. They had explained that Bulgaria had a large and expanding meat industry and they wished to avoid dependence upon imported vegetable protein supplements used in the preparation of feed for the animals. The expert asked whether Bulgaria might consider the exchange of SCP made in a Middle East oil producing state (which was not named) for meat produced in Bulgaria, noting that the Middle East countries were beginning to be increasingly dependent upon food imports.

Mr. Mishev said that the idea was certainly attractive. Bulgaria already exported considerable quantities of meat to Middle Eastern countries. Nearly all trading by Bulgaria was on an exchange or barter basis. The Middle Eastern countries paid for their meat imports with oil which Bulgaria did not really want because it was an obligatory consumer of Russian oil. They would, Mr. Mishev thought, greatly welcome being paid in SCP instead.

Mr. Mishev undertook to put the proposal to Mr. I. I. Ilief formerly Counsellor, Economic Affairs, Bulgarian Embassy in London but now holding a senior position in the Bulgarian Ministry of Chemical Industry. Mr. Mishev undertook to communicate with the expert in due course.

8. Kuwait United Poultry Company (KUPCO)

Mr. Mohamed Al-Fraih (Managing Director)

Mr. Mohamed Al-Fraih supplied the following figures:

Item	Present		Additional projected production	
	Produced	Imported	First stage	Five years
Broilers (million)	5	8	4	15
Eggs (million)	35		50	200
Feed (t/yr)	20,000		25,000	100,000

All feed is mixed locally from imported materials which are mainly soya meal, corn from Thailand, and alfalfa.

A seed-crushing plant has recently been brought into operation and will produce 15,000 t/yr of oils and fats. The co-production of about 60,000 t/yr of meal, corresponding to about 24,000 t/yr of protein, will be more than sufficient for the total of 120,000 t/yr of feed to be produced in five years time; the surplus may be used for ruminant's feeding. Kuwait will become independent of imported meal but will, of course, still have to import the oil-seed.

There is a fish-meal plant in Kuwait but it is not used because there are no supplies of fish.

The present eggs, broiler and feed industry is privately owned. The expansion will be carried out by KUPCO, a State-owned organization, which will produce its own feed.

9. Al-Homaizi Cattle and Poultry Feed factory

Al-Homaizi mixed poultry feed from Thai corn, protein concentrates imported from Holland and soya meal imported from the United States of America. No fish-meal was used directly but was included, it was thought, in the concentrates. Formulations were specified by the concentrate suppliers. There was no attempt by the feed customers to specify requirements. There was no integration between feed manufacturers and poultry producers.

On the day of the meeting (12 January 1977) the cost of soya meal (44% CP) was $306/t c.i.f. Kuwait. Feed was sold at KD 96/t (about $316/t).

The total production of animal feed in Kuwait was estimated at 15,000 t/yr. Al-Homaizi made 8,000 t/yr.

There was a large project for the production of 400,000-500,000 sheep per year in Kuwait.

10. <u>Animality Wealth Co.</u>

Mr. Mohammed A. Karim N. Al-Homaidan (Managing Director)

Mr. Al-Homaidan said that 20,000 t/yr of animal feed were produced in Kuwait. A typical composition was 10% animal protein, 24% soya meal, 66% corn.

11. <u>Livestock Transport and Trading Co. (LTT)</u>

Mr. Suleiman

At present Kuwait imports nearly all its meat. LTT has its own ships and keeps livestock in Kuwait for a short time until they are slaughtered. Mr. Suleiman considered it risky to rely so heavily on meat imports and would like to replace some imports by locally produced animals.

LTT (which is part government, part privately owned) has planned a prototype sheep farm which will have 25,000 breeding ewes. LTT is thinking also of production in other Arab countries (e.g. Syria, Lebanon) where agricultural conditions are better.

LTT also imports chilled meat.

LTT has its own animal feed factory. It is not tied to any particular source for feed components and buys freely throughout the world. Some local materials are used, e.g. dates from Iran and Iraq, and wheat bran from the local flour mill. Recently seed crushing has started in Kuwait.

Mr. Suleiman, who was formerly Director of Animal Husbandry, is a consultant to the Kuwait Dairy Company, which is the biggest in the Middle East and which formulates its own feed. All kinds of meal are used.

The ruminants' feeds contain a minimum of 12% protein. For feeding the animals before slaughter, about 1,000 t per month of total feed are used. Dairy cows use another 1,000 t per month.

A sheep is 110-120 lb (50-55 kg) at slaughter. The dressed carcase is 25 kg.

Mr. Suleiman said that there were technical and administrative problems to be overcome (and implied that the latter were the more difficult) but, taking an optimistic view, in 5 years time perhaps 40-50% of Kuwait's meat requirements would be produced locally.

Ruminants need roughage in their diet. This is very expensive to import so some alfalfa is grown locally.

The reproduction rate of sheep varied from 0.8 to 1.8 lambs per year. The new enterprise might achieve 1.5.

12. Kuwait Dairy Co.

Mr. M. C. Abu Salah, Deputy Manager

The Kuwait Dairy Co. (KDC) has 1,800 animals of which 800 are milking cows; the rest are bulls, calves and heifers. There are 10 small associated farms around the KDC factory which also have a total of 1,800 animals including 800 milking cows.

KDC produces 8 t/d of milk; and the associated farms also 8 t/d, a total of 16 t/d. This quantity will be increased to 25 t/d in 3-4 months time. The total number of milking cows will be increased to 5,000, to be accomodated in a new factory opposite the present one, in the next five years.

More than 90% of KDC production is fresh milk, the rest being cheese, yogurt etc. The outlets are private householders, institutions and supermarkets. Production is only 13% of consumption, so that there is considerable scope for increase.

Feed components are imported and mixed by KDC. Imports are of three kinds:

(a) Concentrates: bran, oilcake, corn;
(b) Fodder, especially alfalfa;
(c) Straw.

At present 15 ha is planted for the production of alfalfa: production falls short of requirements and the balance is imported from Iran and Iraq. There is a plan to increase the area for alfalfa production to 9 million m^2 (900 ha), to be fertilized by sewage sludge.

At present KDC uses annually:

	400 t	ground nut meal
	150 t	sesame meal
	250 t	cotton seed meal
	45 t	soya meal
Total	845 t	

Milk replacer is used for rearing calves from ten days (before which natural milk is used) and three months (after which a special diet is used). KDC import at present annually 350 bags of 25 kg (= 8.75 t) of milk replacer from Denkavit and others.

Many Kuwaiti keep one or two cows.

C. Technology, engineering and costs

13. BP proteins Ltd

Mr. C. H. Green, Licensing and Joint Ventures Manager, was visited at the headquarters of BP Proteins Ltd, Longbow House, Chiswell St., London, on 21 December 1976 in order to discuss the BP policy relating to the licensing of its SCP technology. The following points emerged:

1. The 100,000-t/yr Italproteine plant in Sardinia, which was jointly owned by BP and ANIC, had just been commissioned. On 21 December the plant was producing at 2-t/h and had made 50 t of SCP product. No difficulties had arisen.

2. Construction of the plant in Venezuela, in which BP had a 20% share, was about to start.

3. BP was prepared to consider licensing and management contracts, but was reluctant to invest unless the SCP project was clearly profitable which, in most cases at the present time, it was not.

4. BP would not disclose to a consultant investment cost estimates, partly because of difficulty of stating generalized figures and partly for reasons of confidentiality. BP would also not disclose possible licence fees because such disclosure might prejudice subsequent negotiations.

5. BP have already offered their SCP technology to Kuwait for use in a pilot plant or in a small commercial plant of, say, 20,000 t/yr. BP has a special relationship with Kuwait.

6. There is no normal paraffin separation plant in Kuwait. Kuwait crude, like that of Iran, has a rather low paraffin content.

14. Shuaiba authority

Mr. Mohamed Nassar, Chief, Research Section

Mr. Nassar explained that, to qualify for realization at Shuaiba, a project had to satisfy all the following requirements:

Large size

Petrochemical

Port facilities

It was clear that the SCP project would satisfy these requirements and could be built at Shuaiba.

Mr. Nassar supplied:

(a) An illustrated brochure "Shuaiba Area Authority";

(b) Codes of practice and environmental guidelines including:

Sea water analysis

Monthly average sea water temperature

Specification of distilled water

Analysis of blended potable water

Average composition of gas (from Burgan). (It contains 57% CH_4, 20% C_2, 12% C_3, 5% C_4, 2% C_5, 3% C_6, 2% inerts, 0.17% H_2O, 0.000813% RSH.)

Rainfall

Temperature by month

Air pollutant maxima

Water pollution criteria (COD and BOD: 2.0 ppm desirable, 4.0 ppm maximum)

(c) Land rent, service utility charges and port charges;

(d) Land soil investigations;

(e) Site and harbour plan (scale 1/5,000).

Services supplied include piped sea water, desalinated water, electricity and gas. Steam is not a site service; pass-out steam from the generating station is used in the desalination plant.

Cement is made on site. Some structural steel can be fabricated nearby.

Kuwait is not in an earthquake zone.

Plants may be of any height. The airport is some distance away.

Mr. Nassar promised to supply information of maximum equipment size that could be handled. So ar as dimensions were concerned, the limitation would be the height of overhead electric cables.

There is an Industrial Gases Establishment producing liquid nitrogen, liquid oxygen and orgon.

Mr. Nassar ascertained that no refrigeration process cooling was used at Shuaiba (except as part of the ammonia plant).

15. Petrochemical Industries Corporation (PIC)

Dr. Brinsley Sheridan and Mr. Terence F. Baker, Corporate Planning and Development Department

The state-owned organizations concerned with the exploitation of Kuwait's petroleum resources are:

Kuwait Oil Company (production)
Kuwait National Petroleum Co. (refining)
Petrochemical Industries Corporation (PIC) (petrochemicals).

PIC was formed in 1963 as a joint company with Gulf and BP who were bought out in 1973 to make PIC wholly state-owned.

PIC produces mainly ammonia and urea but also some chlorine.

Urea, 2,500 t/d, is produced by the Stamicarbon process. Nearly all is exported.

Ammonia, 2,000 t/d, is made mainly to supply the urea plant but with a little over for export. The Montecatini process was used for the original ammonia plant, and the Topsoe process for the extension.

PIC is currently planning an aromatics plant requiring an investment of $300 million. Using naphtha feedstock, it will make 280,000 t/yr of benzene, 60,000 t/yr o-xylene, and 85,000 t/yr of p-xylene. The feasibility and marketing studies are complete. The project was to have been carried out in co-operation with Grace who has, however, recently withdrawn from the project. PIC has not the resources to realize the project themselves and may have to employ an engineering firm to help them.

There was also an ethylene project, whioh also would require an investment of about $300 million, to make 320,000 t/yr of ethylene from ethane. The ethylene would be used to make 120,000 t/yr LDPE, 120,000 t/yr styrene and possibly styrene as well.

Kuwait Oil Company is commissioning a plant to separate LPG from natural gas for export. All gas is associated gas and, as produced, contains 61% methane and 37% heavier hydrocarbons. The calorific value is 1,333 Btu/SCF. The removal of hydrocarbons as LPG will considerably reduce the available amount of gaseous fuel, which is used mainly for firing electricity generating stations.

PIC considered that the construction cost of a plant in Kuwait was about 35% higher than in the United States. The increase was made up equally of additional freight costs, increased erection cost caused by lower labour productivity, and extra design features including additional spares.

Offsites were at the same level as in the United States and typically 35%.

It was possible to have maintenance done on contract. Foster Wheeler has a joint venture maintenance company which can, for instance, retube heat exchangers.

PIC considered that the simultaneous execution of more than one large project in Kuwait would create unacceptable strains.

Plant construction times were only slightly longer than in the United States and Europe: 3 years was typical.

All jobs were put out to competitive tender; there were no favoured contractors. Foster Wheeler had built plants for PIC and Kuwait National Petroleum Company (KNPC). Fluor had built the KNPC refinery. Topsoe had been the main contractor for the latest ammonia plant; Chiyoda had built the urea plant and Lurgi had undertaken the procurement. SNAM had debottlenecked the refinery and Coppee-Rust the urea plant. Foster Wheeler was probably the strongest contractor in Kuwait; it had a share in KROMENCO, a maintenance organization.

Maintenance costs a little more in Kuwait than in Europe. Provision of spares, both installed and non-installed, had to be higher than in a developed country that had ready access to spares.

Problem-solving was slow and therefore unsatisfactory without foreign back-up. Communications overseas were very good.

Temperatures

Sea water has a normal maximum of 33°C with peaks to 34°-35°C. In winter the temperature is 13°C.

In summer, the average daily maximum temperature (dry bulb) is 45°-49°C, and the maximum 50°C. The average daily minimum temperature is 24°-27°C, and the minimum 0°C (non-freezing).

The summer average maximum humidity is 50%. The winter average maximum is 35%. Typical summer wet bulb temperatures are 28°-29°C with a maximum of 33°C.

Costs

The stream factor of a Kuwait plant was about 90% of that of a European plant.

Operating staff and labour cost 50% more because of higher manning and high salaries paid to expatriate staff.

For the purposes of a DCF calculation, production in the first four years after plant completion is assumed to be 50%, 80%, 90%, 100%.

Phasing of construction expenditure was normally assumed to be 20%, 65%, 10%, 5%. For DCF calculations 20%, 60%, 20% could be used.

D. Technical resources

16. Department of Agriculture (Ministry of Public Works)

Milk production

Mr. Ibrahim M. Hujaij

In order to reduce Kuwait's dependence upon imported milk, a programme for increasing milk production in Kuwait was started in 1960. Friesian and Jersey cows were imported and their behaviour under Kuwait's climate conditions had been studied: the temperature inside a barn may reach 110°F (43°C) and humidity may reach 92%. It was found that the animals thrived and gave good milk yields. Accordingly, the breeds were recommended for use in Kuwait. There are now 16-18 dairy farms with a total of 3,500-4,000 animals.

Local breeds, although tolerant to the climate, give only low milk yields. Owners of cows of local breed are invited to have them mated with pure-bred bulls. Big farms are encouraged to use pure-bred stock.

Local production of fresh milk is now 10%-13% of consumption. There is a subsidy of 50 fil/litre. Cost of production (because of the high cost of imported feed) is 200-250 fil/litre. After the first week or so calves are fed milk replacer at only 8-10 fil/litre.

There is a project to import 1,000 female calves per year. These will be artificially inseminated at the government farms and then sent to private farms at the age of 5-7 months. In this way it is intended to avoid the expense of importing cows at KD 400-KD 800 each.

Mr. Hujaij was not able to state the consumption of milk replacer because it was all imported and used privately.

Meat production

Mr. Ibrahim M. Hujaij

Kuwaiti prefer mutton to beef. Of all meat eaten, 64% is mutton or lamb, 12% beef and buffalo, and about 20% canned and prepared.

The Livestock Transport and Trading Co. imports large quantities of live and frozen mutton and lamb. In 1976, 52,000 animals were imported. The same company plans to increase production to 100,000 animals in Kuwait and Syria. (The target of 500,000 mentioned by Al-Homaizi is more distant and less firm.)

Ruminants' feeds are compounded from bran, barley, corn and protein concentrate. The Department of Agriculture (Mr. Hujaij) had carried out tests in which part of the protein was replaced by urea in the diets of cattle and sheep. It was found that up to 3% urea in the diet could be used; above this level some animals had become blind.

The Department's research station, which was briefly inspected, employs 36 graduates.

Poultry

Mr. Mohammed Mohtadi

Of the total consumption of broilers in Kuwait, 50%-60% are now locally produced. Local production of eggs is 15% of consumption.

Mr. Mohtadi believes that an SCP plant in the area is necessary - if only to control soya meal price and secure supplies.

Broiler consumption in Kuwait was currently 16 million and would rise to 20 million in a few years. Current consumption of eggs was 200 million.

Feed formulations were normally specified by the major suppliers of protein concentrates, e.g. Ralston Purina. The energy content of chicken feeds was reduced in summer so that the protein content of feed rose from 17% to 19%. There was no integration between the feed producers and consumers, although from time to time the Department brought them together for conferences and consultations.

17. <u>University of Kuwait</u>

<u>Department of Chemistry</u>

Dr. Jassim El-Hassan, Head of Chemistry Department

Dr. Mousa Ajam, Chemistry Department

It was explained to Dr. Jassim El-Hassan that the proposed SCP plant in Kuwait would require:

(a) Technicians on shifts to monitor plant performance;

(b) Knowledge and experience of microbiological process by the plant management to permit recognition of abnormal conditions and their likely causes;

(c) Institutional facilities in Kuwait, under the direction of research microbilogists, for the investigation and solution of unusual problems;

(d) Continuing support from the process owners in updating knowledge of the micro-organism, and in the solution of problems that cannot be handled in Kuwait.

Dr. Jassim El-Hassan said that he was the only protein chemist at the University. Biochemistry formed a section of the Chemistry Department which turned out about 19 graduate biochemists per year. Dr. Jassim El-Hassan was willing to reorganize the courses and structure of his department to meet the needs of an SCP plant, once the needs had been explained to him.

The production of technicians (persons trained to below graduate level) in Kuwait was unsatisfactory, he said, and constituted a weakness in the Kuwait economy. At present the University carried out investigative work on behalf of industrial companies at its own expense. There was no shortage of funds; but the statutes of the University were being changed and in two or three months time it would be possible to undertake sponsored work.

Department of Botany

Dr. F. J. Lynch

There is a microbiology section in the Department of Botany.

It was explained to Dr. Lynch that a Kuwait SCP plant would need microbiological technicians for plant control, a plant management knowledgeable in microbiology, and institutional facilities under the direction of research microbiologists for problem-solving.

Dr. Lynch said that the University did not train microbiologists to less than graduate standard. Some twenty microbiologists graduated each year. There was little employment opportunity for these people, who where reluctant to accept the apparently inferior status of technician. Dr. Lynch thought, however, that this psychological barrier could be overcome.

There was a College of Technology in Kuwait which produced technicians, but not in microbiology.

Dr. Lynch thought it would be difficult to find a suitably qualified and experienced Kuwaiti to become plant manager of an SCP plant. Plant management would, he thought, have to to provided by expatriates for a few years.

The teaching of microbiology in the University could if necessary be reorganized to meet the needs of an SCP plant in 1984/85.

18. Kuwait Institute of Scientific Research

Dr. Ibrahim Hamdan (Food scientist)
Dr. A. J. Salman (Nutritionist and biochemist)
Dr. Omar (Director of research)

Dr. Hamdan supplied a "Draft for statement on single cell protein", and outlined the present and proposed activities of the Institute in this field, which were:

To study costs

To evaluate known processes

To search for a thermophilic organism

To undertake nutritional and safety testing of SCP

Dr. Hamdan explained that it was not the intention of the institute to repeat the work already done by major corporations; they did, however, want to acquire enough expertise to permit them to evaluate existing technologies offered to Kuwait and to enable them to provide a nucleus of experts to assist in the operation of an SCP plant in Kuwait, in problem solving, and in the training of personnel.

The Institute recognized the advantages of having a thermophilic organism in the climatic conditions of Kuwait and had produced in the laboratory small quantities of SCP from a thermophilic organism.

There was a discussion on the proposed work programme which included the construction of a general purpose "pilot" plant (or " semi-technical") incorporating a 1,500 litre fermenter. The expert expressed some doubts about the utility of such an installation as a research tool and as a means of evaluating existing developed technologies. For instance, the general purpose fermenter would not be able to reproduce the conditions in an ICI fermenter which was of completely different design. A great deal of money and time would be spent in achieving and maintaining satisfactory operation of the plant before any results of value would be obtained. The behaviour of an SCP micro-organism could best be studied in laboratory fermenters. However, the proposed plant would certainly be of value in producing larger quantities of product from a new micro-organism than could be produced in the laboratory; such quantities would be needed for animal feeding trials.

The expert thought that there would indeed be a case for carrying out animal feeding trials in Kuwait not only on new products but also on established products such as those of BP and ICI. Chickens were reared in open houses in Kuwait in particularly extreme climatic conditions.

The formulations were specified by the European suppliers of protein/mineral concentrates. Although these formulations were undoubtedly made with considerable scientific knowledge, they might not necessarily be ideal for Kuwait. The energy component in Kuwait feeds was corn from Thailand.

Dr. Hamdan said that, so far as toxicity testing of a new product was concerned, the tests would better be done by an institute in Western Europe or the United States. With this the expert agreed; he pointed out, however, that full testing, including multigeneration tests, would take several years and cost a lot of money. For this reason organizations such as ICI and BP would be reluctant to change to a new organism: instead, they would prefer to develop further the processes based on the originally selected micro-organisms.

The possibility of improving a strain for thermophilicity or reproduction rate by natural selection in a continuous process by the application of stress - high temperature or high dilution rate - was briefly discussed.

The expert supported a proposal by the Institute to carry out storage trials of SCP under Kuwaiti conditions, whioh involve high temperature and high humidity in summer, in order to determine whether air-conditioning of the storage buildings would be needed.

Kuwait Institute of Applied Technology

Dr. Ali Sheab

The visit was made to ascertain the ability of the Institute to train technicians needed by a SCP plant.

There is a well equipped Chemical Industries Department with a staff of six scientists (Ph. D level). Its work is at present concentrated in the petrochemical field. Microbiological training is not at present carried out but could be without difficulty started at about year's notice. Nearly all staff are expatriate, as would be any microbiologists.

Boys are taken from school with the equivalent of a United Kingdom Ordinary National Certificate. The course at the Institute lasts 2½ years and includes some experience within industry. About 150 students, all Kuwaiti, leave each year with the equivalent of Higher National Certificate. Leavers were free to seek employment anywhere, so that it would be necessary to train more technicians than the SCP plant would need.

Dr. Sheab hoped and believed that the Institute would eventually serve the region and not just Kuwait.

Annex III

EFFECT OF VARYING ASSUMPTIONS ON THE ESTIMATED PRODUCTION COST OF SCP

Effect of varying assumptions about the loan interest rate and the price of gas and electricity upon the estimated production cost of SCP in a 300,000-t/yr plant using the ICI process is as follows:

	$/t		$/t
1.72 t methanol ($100/t)	172		172
0.056 t P_2O_5 ($500/t)	28		28
0.147 t ammonia ($120/t)	18		18
Other materials	20		20
1.28 t steam ($5/t)	6		6
12.2 MMBtu gas ($1/MMBtu)	12	($0.034/MMBtu)	1
2600 kWh electricity ($0.0067/kWh)	17	($0.0033/kWh)	9
1230 m^3 sea water ($0.0067/$m^3$)	8		8
4 m^3 pure water ($0.18/$m^3$)	1		1
Other services	1		1
Total variable	283		264
Royalty (3% of selling price)	15		14
Maintenance (4% of fixed capital)	32		32
Wages and salaries	5		5
Other fixed costs	6		6
Total fixed	43		43
Depreciation	82		82
Interest on loan (8%)	55	(5%)	34
Dividend on equity (15%)	38		38
Total capital-dependent	175		154
Total selling price	516		475

Notes: 1. The gas price of $0.034/MMBtu corresponds to 14 fil/1,000 ft^3. 2. The electricity prices of $0.0067 and $0.0033/kWh correspond to 2 fil and 1 fils/kWh respectively. 3. The prices at which SCP could compete with soya meal (on a contained protein basis) are estimated to be currently $501/t in the domestic market and $450/t (max.) in the export market.

Annex IV

EXTENDED FEASIBILITY STUDY

The following steps (in approximate order of priority) are recommended for any extension of the feasibility study:

1. Continue discussions with international feed commodity traders to ascertain the terms under which they might handle exports from a Kuwaiti SCP plant and the price that they would pay for the product.

2. Enter into discussions with process owners in order to:

(a) Evaluate the technology and determine costs accurately;

(b) Ascertain licence terms and conditions;

(c) Determine the process owner's attitude to his possible investment, or to a management contract, to secure his committment to the continuing success of the plant;

(d) Explore the possibility of the process owner undertaking export marketing, and his terms.

3. Make or obtain forecasts of price changes over at least ten years for:

Soya meal
Basic energy
Methanol
Normal paraffins

From these, calculate the future profitability of an SCP plant. (It is possible that much of the required information could be supplied by United Nations agencies such as the Food and Agriculture Organization of the United Nations and the International Bank for Reconstruction and Development.

4. Examine the feasibility of co-operation between the Gulf States (many of which are known to be planning their own SCP plants), and the economic advantages of such co-operation, in the following possible ways:

(a) A single co-operatively owned SCP plant in the Gulf area;

(b) A single feedstock plant (n-paraffin or methanol) in the Gulf area supplying more than one SCP plant;

(c) A co-operative or common marketing organisation;

(d) A common marketing policy; for instance, to fix prices;

(e) Exchange of technical information; common or co-operative problem-solving facilities;

(f) Common design features and spares, e.g. for compressors and refrigeration sets.

5. Arrange storage trials of SCP under Kuwaiti conditions.

6. Discuss plans with Kuwait University, Kuwait Institute of Scientific Research, the Kuwait Institute of Applied Technology, and other appropriate bodies for the training of the technicians and technologists needed for the operation of an SCP plant; and for the provision of problem-solving facilities.

7. Arrange nutritional trials to confirm the effectiveness of SCP in animal diets formulated with ingredients normally used in Kuwait and under Kuwaiti climatic conditions.

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