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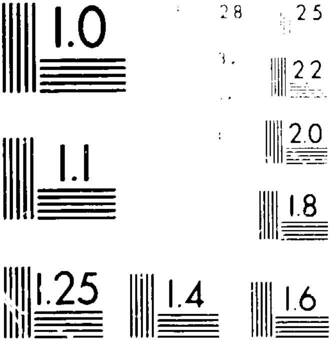
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org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THE EFFECT OF ENERGY AND INVESTMENT COSTS ON TOTAL FERTILIZER PRODUCTION COSTS*

prepared by

William F. Sheldrick
Fertilizer Advisor
Industry Department
World Bank

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1.0 SUMMARY AND CONCLUSIONS

Energy and Capital Related Costs are usually two of the most important components of total production costs for fertilizers and the main objective of this paper has been to review the effect that these two items are likely to have on fertilizer production costs, and hence on fertilizer prices in the future.

The paper updates the investment cost data for the principal nitrogenous, phosphate and potash fertilizers, particularly those which form the basis for the fertilizer export market. The main cost factors in fertilizer manufacture such as raw materials, energy and investment can vary significantly for different site locations and it is important to take this into account when projecting total fertilizer production costs and prices. Sometimes raw materials and energy may be available cheaply but this advantage can be offset by higher investment costs and lower operating rates.

In order to appreciate more fully the factors which influence fertilizer costs a "cost envelope" has been developed for the major fertilizer materials which can be easily used to assess fertilizer investment and production costs for different situations.

Nitrogen Fertilizers

The study shows that for urea production, the cost of energy and capital related costs are equally important and that other costs are relatively small. Until recently, many developed countries had both the advantage of cheap energy and low investment costs but this advantage is disappearing as natural gas prices in these countries rise to the level of fuel oil equivalent energy prices and also as it becomes relatively cheaper to build, and easier to operate, plants in developing countries. At the present time there is a trend toward a more balanced situation where overall production costs in different locations are similar but undoubtedly the effect of increasing energy prices generally will eventually favor those areas where there is very cheap natural gas. For example in the Middle East, USSR, etc. ammonia and urea production and export is probably still one of the most attractive ways of utilizing low opportunity cost gas which would otherwise be flared. Based on the estimates made in this report, the total production cost of producing urea, including the capital charge to ensure an adequate return on new investment would probably have to be in the range of $275-300/ton.

Phosphate Fertilizers

Phosphate fertilizers are not so energy dependent as nitrogen fertilizers and overall the cost of energy to produce one ton of triple superphosphate is 10% or less of total production costs. There is also still considerable scope to effect further energy recovery in phosphate fertilizer manufacture which may to some extent offset future increases in energy prices. Overall, capital related costs dominate the cost of producing phosphate fertilizers indicating the difficulty of establishing phosphate mines and fertilizer complexes on new developing sites. The estimates also show the importance of the cost of sulphur on overall production costs and the dependency of the industry on this element. Using a present sulphur price of $160 per ton c.i.f. the total cost of producing phosphoric acid in the future on a developed site is likely to fall within the range of $425-450/ton P_2O_5. For TSP the total cost of production is likely to fall within the range of $200-230/ton of product.

Potash

As most new capacity for potash outside the Centrally Planned Economies will be developed in Canada, total production costs in that region will have a major influence on future selling prices. The energy cost for dry underground mining of potash will be 15% or less of total production costs. Anticipated increases in real energy costs in the next few years particularly in Canada are not likely to affect product cost ex-mine by more than a few dollars per ton. The capital related costs are by far the main consideration, particularly in view of the very high cost of sinking new potash mines to a depth of 3,000-4,000 ft. Total production costs ex-mine in Canada are estimated to fall between $80-90/ton but transport to a port will cost about $30 more. These costs do not include reserve taxes.

<u>ANNEXES</u>

2.0 INTRODUCTION

The cost of energy and capital related costs are normally the two most important components of the total factory-gate cost of producing fertilizers. This is particularly so in the case of nitrogen where hydrogen or hydrocarbon fuel is also required as feedstock.

The relative costs of energy and project investment can vary considerably depending on location. For example, it is possible to have similar production costs for a nitrogenous fertilizer such as urea, in two different locations, where in one place energy may represent about 60% of the total production costs and in the other case only 10%.

Although it is relatively easy to predict the effect of energy costs on fertilizer production costs, it is extremely difficult to predict the future cost of energy particularly for natural gas at specific locations. At the present time the price of gas for ammonia plants in different parts of the world, and even within some countries, can vary considerably.

Overall the effect of energy and investment costs on production costs and hence on fertilizer prices is complicated by many factors usually very specific to each location. The main objective of this paper has been to review the availability and cost of energy in various regions for fertilizer manufacture including the effect of new technical developments on future energy use. The paper also examines the effect of fertilizer investment on overall production costs.

The cost data are based on those contained in a paper to the Fertilizer Commission in Rome 1980 (Ref. 1) suitably adjusted for international inflation and technical developments. The major components of production are presented in graphical form so that the relative components of production cost such as energy and capital related costs can be readily compared for different types of location.

3.0 GENERAL CONSIDERATIONS

3.1 Energy Requirements to Produce Chemical Fertilizers

Before considering the impact that future energy prices are likely to have on fertilizer production costs, it is important to know the quantity of energy that is required to manufacture different fertilizers. Unfortunately many of the standard fertilizer handbooks on the subject, relying usually on information released by engineering companies, are based mainly on battery limit requirements during equilibrium operation, and often significantly underestimate the overall energy requirements. Allowance must also be made for the cost of operating infrastructure or for transient operating conditions when a plant is starting up or closing down, or periods of malfunctioning.

The Fertilizer Institute (T.F.I.) of the U.S. in 1980 carried out a very useful survey of its members (Ref. 2) which provided the following information on energy requirements for fertilizers. In order to be consistent with other information in this paper, T.F.I. information has been converted from short to metric ton of product.

Average Requirement per Metric Ton of Product - 000's BTU's

	Nitrogen (Urea-46%N)[a/]	Phosphate (TSP-46%P_2O_5)[b/]	Potash (KCI-60%K_2O)[c/]
Natural Gas	30,552	920	1,356
Electricity	2,334	2,600	1,063
Fuel Oil	26	730	1
Imported Steam	6,152	360	-
TOTAL	39,064	4,610	2,420

a/ Based on ammonia plants using centrifugal compressors.
b/ Total estimated energy including rock production and energy recovery from sulphuric acid manufacture.
c/ Based on shaft mining.

All energy estimates have been expressed in terms of equivalent fuel requirements and electrical and mechanical power and steam have been converted into the amount of fuel required to generate them. It is assumed that a new major project would use an integrated energy scheme, and as far as economically possible all energy saving devices would be incorporated. Nevertheless the energy consumptions estimated for each fertilizer are those considered reasonably attainable rather than based on theoretical considerations. In some cases it is assumed that a new plant will do significantly better than the average figures from the T.F.I. Survey. Where no other data are available T.F.I. average consumptions have been used.

In the case of nitrogen a number of scenarios have been examined in which different gas prices have been assumed. In other cases an energy cost of US$5.5 per million BTU has been used as the 1981 energy equivalent fuel oil price. It is appreciated that in some locations the price of energy may differ from this assumption but in these cases the likely deviation in cost is discussed.

3.2 Investment Cost Estimates

Investment costs for fertilizer plants can vary widely depending on site location and infrastructural requirements. Unfortunately some major surveys in the past have presented a misleading indication of the full production costs by using only battery limit investment costs. Although these procedures may be appropriate in evaluating expansion programs on existing sites, for new projects on green field sites, the full cost of infrastructure and working capital must be included.

The range of investment costs used for each fertilizer material is based on many projects appraised by the Bank and others, all updated to mid-1981 U.S. dollars. As in Ref. 1 it has been found convenient to categorize projects roughly under three major headings.

(a) A developed site — a site with existing infrastructure in which most of the supporting facilities will already exist. For example there will be roads, a port, railroad, a social infrastructure that could provide workers to build and operate the plants. Equipment can sometimes be provided from local sources and can usually be maintained using local facilities.

(b) A developing site -- in this case there will be some fertilizer and social infrastructure already existing which can usefully contribute towards the project but not as much as for case (a). Local specialized services will be limited.

(c) A developing site in a remote location -- in this case there would be no supporting facilities of any sort available and all roads, ports, railroads, civil works amenities, etc. would have to be provided as part of the project cost. All equipment will have to be imported. Most of the labor to operate the plant will have to be brought in from outside.

In specifying these categories it is intended that they be used basically as a guide. For example it is appreciated that some projects in developing countries with developed fertilizer infrastructure might well fall into category (a). Similarly there might be plants in remote locations in developed countries which would require extensive and expensive infrastructure. In order to allow easier interpolation the investment data have been presented in graphical form with a range of specific investment costs for each category. The value of investment cost at the lefthand ordinate on the graph approximates to the battery limit costs of the plant on a developed site. The investment cost to generate steam and electricity starting with gas or other fuels has been included in the total plant cost.

3.3 Basis for Calculating Production Costs

By far the most important factor affecting capital related costs and of course other fixed costs is plant utilization rate. Most projects are evaluated on the basis of a 90% utilization rate after allowing for a phasing-in period for the new capacity. In some cases particularly in developing countries this assumption may be too optimistic. The effect on production costs of operating at low operating rates are covered in detail in Ref. 1; Figure 1 also indicates the penalties of poor utilization in gas price equivalents. For example for a plant with high investment costs such as a developing site in a remote location, the effect of operating at 70% rather than 90% is equivalent to having to pay an increased gas price of US$2.0 per million BTU.

A simplistic capital charge of 15% per annum on total annual investment has been used. Other capital related charges for the fertilizer plants have been taken as; depreciation 8-1/3%; maintenance 3% of total plant investment cost and annual insurance 2/3% of total plant investment cost. In the case of phosphate rock and potash, production and capacity are assumed to be the same. The mine is depreciated over 20 years and the value of the ore in the ground has been considered as part of the initial investment cost. For the process plants for nitrogen and phosphate fertilizers, 90% utilization has been used. A delivered cost of sulphur of $160 per ton has been used to calculate the cost of producing phosphate fertilizer.

All monetary values used in the report are in mid-1981 U.S. dollars.

4.0 NITROGEN FERTILIZERS

4.1 General

The use of urea as a fertilizer has expanded rapidly during the past decade to about 35 million tons. Urea is the most dominant nitrogen fertilizer in international trade and as it is likely to remain so, it has been used as a basis for the cost estimates in this paper. Although larger plants have been built, the fertilizer complex comprising plants to produce about 1,000 t.p.d. ammonia and 1,650 t.p.d. urea is probably still the most popular economic consideration. As natural gas is the most popular feedstock and fuel, the investment costs are based on the use of gas, but as presented, in terms of "investment per annual ton of capacity" the data contained in the graphs can also be used for other feedstocks.

Investment cost data used to represent the range for the varying scenarios have been based on the most advanced ammonia and urea technologies. There are some indications that in nitrogen fertilizer projects the relative costs of investment for developed and developing sites is diminishing somewhat and some allowance has been made for this. This difference in costs should diminish further as developing countries build up their infrastructure and engineering capabilities. The establishment of industrial estates which is taking place in several Middle East countries and the erection of additional plants on existing sites will also help reduce unit investment costs in developing countries. Even so, total investment costs for new nitrogen plants can still vary more than two-fold depending on site location and infrastructural requirements.

Alternative uses of gas include the fertilizer and petrochemical industry such as methanol, or for LNG manufacture for overseas markets. Generally, because of their similar investment and processing costs, the economics of methanol and ammonia manufacture are similar. Where deposits of gas are small, ammonia and urea plants are usually the most attractive proposition. Where deposits are large LNG manufacture may be feasible. Even so, the cost of liquification and transport of natural gas is expensive and as can be seen from Figure 2 the net-back value of the gas can vary from about \$1.0 to \$2.5 per million BTU, depending on location of deposit and market.

Opportunity costs for ammonia manufacture in many areas would vary between \$1.0 - 2.5 per million BTU. In some cases, particularly where gas is being flared and has no apparent alternative immediate use, the opportunity cost for the gas is basically that of collection and sweetening which would usually be less than \$1.0 per million BTU.

Although the opportunity cost will set the lower level of gas price on which economic returns are calculated, in many cases financial prices are set at a higher cost depending on what the market will bear.

4.2 Energy Requirements

The cost of natural gas used as a fuel and feedstock for ammonia and urea production is becoming increasingly important in determining the economics and location of future nitrogen fertilizer plants. The Fertilizer Institute Survey indicated that the average energy consumption to produce one metric ton of urea in the U.S. is about 39 million BTU which is in good agreement with the assumption made in Ref. 1 of 35 million BTU. Although significantly lower figures are now claimed for energy consumption it is assumed in this paper that the energy consumption will fall to 32 million BTU per metric ton of urea. This figure however would also include bagging operation costs which would be about 0.6 million BTU per ton of product bagged. Energy costs have been calculated for a range of gas prices from US$1.0 to US$5.5 per million BTU. The results are given in Figure 3.

4.3 Availability and Opportunity Cost of Natural Gas for Nitrogen Fertilizers

As natural gas is expected to remain the dominant feedstock for nitrogen fertilizer plants throughout the 1980's, those countries which are well endowed with gas are likely to have a competitive edge in nitrogen fertilizer production. The reserves, production and disposition of natural gas throughout the world are shown in Table 1. It is of interest to note that in 1977 about 207 billion M^3 of natural gas were flared, sufficient to feed about 400 x 1,650 t.p.d. urea plants or almost twice the current world production of nitrogen. The ma deposits of natural gas are in Eastern Europe (including USSR) the Middle East and North America. Significant quantities of gas are being flared in Middle East countries, in the USSR and in several African countries such as Nigeria and Algeria.

One of the most important factors determining the feasibility of ammonia or urea production in any country will be the economic (opportunity) value of the particular gas resource available, or to be made available for such production. It is difficult to generalize about the economic value of gas because it varies from location to location depending on the size of the resource and in the alternative (opportunity) uses of the gas if it were not to be used for fertilizer production. If the gas can be used for oil substitution for example, then the economic value of the gas would be linked to the value of oil which in this paper for the basis of comparisons is assumed to be US$5.5 per million BTU. However in many countries, particularly developing countries, there are many occasions where this fuel oil substitution alternative is not available and where the economic value of gas is determined by other alternatives in which gas has a lower value.

Table 1[1/] PRODUCTION AND DISPOSITION OF NG (1977)

(Billion m^3)

Nations	Proved Reserves	Total Production	Reinjection	Flared	Commercial Production	R/P (1)
North America	7,580	699.3	37.3	5.2	656.8	10.8
U.S.A.	5,940	597.6	26.5	3.8	567.3	9.9
Canada	1,640	101.7	10.8	1.4	*89.5	16.1
Latin America	3,070	88.7	25.6	13.1	50.0	34.6
Mexico	850	21.2	0.1	4.1	*17.0	40.1
Venezuela	1,160	37.5	19.9	2.8	14.8	30.9
Other	1,060	30.0	5.6	6.2	18.2	35.3
Western Europe	3,870	192.1	1.0	11.7	179.4	20.1
Netherlands	1,700	96.9	-	-	*96.9	17.5
England	820	44.2	-	3.5	40.7	18.6
West Germany	210	19.2	-	1.1	18.1	10.9
Other	1,140	31.8	1.0	7.1	*24.6	35.8
Africa	5,870	75.7	7.6	40.9	27.2	77.5
Algeria	3,540	26.6	6.2	11.8	*8.6	133.1
Libya	730	20.0	-	4.2	*#15.8	36.5
Nigeria	1,220	21.5	-	21.0	0.5	56.7
Other	1,590	7.6	1.4	3.9	2.3	209.2
Middle East	20,370	161.0	18.2	101.3	41.5	126.5
Iran	14,150	58.5	9.4	27.9	*21.2	241.9
Saudi Arabia	2,410	48.7	6.8	37.4	4.5	49.5
Abu Dhabi	570	15.3	-	12.1	3.2	37.3
Other	3,240	38.5	2.0	23.9	#12.6	84.2
Asia & Oceania	3,480	64.1	2.1	11.5	50.5	54.3
Afghanistan	70	2.5	-	0.1	*2.4	28.0
Indonesia	680	15.1	2.1	7.3	*5.7	45.0
Brunei	230	9.8	-	0.9	*8.9	23.5
Australia	910	6.9	-	0.1	6.7	131.9
China	710	13.2	-	-	13.2	53.8
Japan	20	2.8	-	-	2.8	7.1
Other	860	13.8	-	3.1	10.8	62.3
Eastern Europe	26,360	425.8	-	22.9	402.9	61.9
USSR	26,040	365.0	-	18.8	*346.1	71.3
Other	320	60.8	-	4.1	56.8	5.3
TOTAL	70,600	1,677.3	91.8	206.6	1,397.0	42.1

Note (1) Proved reserves/total production.
(2) Asterisked figures include exports.
(3) Figures with # marks include reinjection.

1/ Reference 3.

4.4 Future Natural Gas Costs for Nitrogen Fertilizer Production in Specific Locations

North America

In 1980 the average gas price to the U.S. fertilizer industry was just under $2.0 per million BTU with prices varying from less than $0.5 to about $3.0 per million BTU. Although the 1978 Natural Gas Policy Act was designed to allow new gas to reach free market levels by 1985 this was based on an energy price of oil that was then assumed to have reached $15 per barrel. In 1981 the U.S. Cabinet Council on Energy and Natural Resources recommended speeding up decontrol of wellhead prices of newly discovered gas. In addition it was urged that prices of currently produced gas also be decontrolled over a three-year period, something that would not occur under present law. However in November 1981 it was announced that the further decontrol of natural gas was likely to be delayed. The natural gas situation in the U.S. is complex with more than 22 categories of gas pricing. Although it is intended to achieve decontrol of gas by 1985 many analysts in the energy field do not expect that gas will immediately reach prices equivalent to fuel oil by 1985 but are more likely to average about 70-75% of oil prices. On the basis of oil prices equivalent to $5.5 per million BTU it is assumed that gas prices by 1985 will approach $4.0 per million BTU. Thereafter the difference between energy prices from gas and oil will narrow very slowly.

In Canada the situation is somewhat clearer. A new National Energy Agreement of September 1981 is such that the "parity relationship" between the wholesale price of gas at the Toronto City Gate and the average price of crude oil at the Toronto Refinery Gate will be approximately 65%. From this agreement it would appear that the price of gas netted back to its source in Alberta could be as low as 50% of equivalent energy prices from oil - say between $2.5 and $3.0 per million BTU.

As a result of the favorable gas prices now prevailing in Western Canada several new projects are being studied in addition to four new plants that will go onstream there in the next five years.

Western Europe

Although a few companies in Europe mainly in Holland, Ireland and UK have favorable gas contracts, most others do not. Europe is already importing natural gas from North Africa and Eastern Europe and in considering the future of nitrogen fertilizers in Western Europe it is assumed that the overall average price of gas will approach the equivalent energy price of fuel oil by 1985.

East Europe (Including USSR)

This region has the largest proven reserves of natural gas and is also the largest producer of gas. The region has also become the largest producer of ammonia and is expected to have a surplus of 4-6 million tons of nitrogen by the mid-1980's, which should make it the largest exporter of nitrogen fertilizers. It is difficult to put a price on natural gas to ammonia plants in the USSR in the future, as this is likely to depend on political as well as economic considerations. The USSR has already exported ammonia at very low prices equivalent in some cases to a negative energy cost. Although the USSR will increase its sales of gas to Europe by pipeline which could net-back to about $3.5-4.0 per million BTU, nevertheless with its large resources of gas it is still in a position to maintain a large nitrogen fertilizer export business with gas at a low political price if it wishes to do so.

Middle East

In terms of gas availability at low economic prices, the Middle East region is extremely well placed to produce nitrogen fertilizers. For many countries in the region flaring large quantities of gas, the opportunity cost will be small, equivalent only to collecting and sweetening the gas which is likely to be below $1.0 per million BTU. When considering LNG as an alternative, the opportunity cost of gas depending on the market would be between $1.0 and $2.5 per million BTU. Taking into account the very large quantities of gas available in the region and the fact that the LNG market may not develop as quickly as expected it seems likely that gas will be available at about $1.0 per million BTU and even below, although as mentioned earlier, gas prices in financial terms may be related to market conditions.

Other Countries with Gas Available for Ammonia Production

Several other countries are in position to provide cheap gas for the manufacture of ammonia and urea for the export business. These include Nigeria, Mexico, Indonesia, etc.

4.5 Estimation of Total Production Costs for Urea for Various Regions

Based on the data in Figure 3 some estimates have been made for total production costs for various locations. In doing this, assumptions have been made for gas prices, investment costs and plant utilization. The gas prices are based on the discussions of the previous section, investment costs are a judgement figure based on experience and information of similar projects in specific regions. The plant utilization in each region is difficult to predict. Many projects are appraised and justified on plant utilizations which in practice are not achieved. In this case, reference has been made to the data base of the World Bank/FAO/UNIDO Fertilizer Working Group which monitors plant utilization for each country. Allowance has been made for the fact that in some developing areas these averages may be depressed because of the relatively high percentage of total capacity which is currently being phased into production.

Table 2

Total Production Costs for Urea for Various Regions

Region	Gas Price $ per Mill. BTU	Investment $ per ton of Annual Cap.	Plant Utilization %	Total Production Cost $ per ton Urea
North America				
U.S.A.	4.0	400	90	275
Canada	3.0	430	90	250
Central America	1.0	600	85	245
Western Europe	5.5	420	90	330
Eastern Europe	1.0	550	80	242
Middle East	1.0	700	80	294
South East Asia A	2.5	600	85	293
B	1.0	600	85	245

The figures in Table 2 can only be regarded as an approximate guide to total production costs and hence future selling prices. The figures contain two main assumptions. The first is that the gap between energy prices for various locations will increase and the other is that the relative advantage in investment costs of the developed over-developing locations will diminish. The overall effect of this trend is to narrow the gap between overall production costs for the various regions. Taking freight costs into account it would appear that no one producer will have a major overall advantage with regard to world nitrogen fertilizer markets with the possible exception of Eastern Europe exporting to Western Europe. The position in the U.S. is finely balanced. If natural gas prices stay below equivalent energy prices of oil as indicated, U.S. domestic production for most areas of the country should be able to meet outside competition although Canada and Central America (Mexico) have the possibility to increase their exports to certain areas of the U.S. and particularly so as gas prices in the U.S. increase to equivalent energy prices for oil.

The case for Japan will be similar to that of Western Europe and in this situation the prospects for new plants in South East Asia such as in Indonesia and Malaysia exporting to Japan and other Far Eastern markets look good.

Although there are many doubts about the parameters for assessing the position of Eastern Europe and particularly the USSR as a major exporter in the future, undoubtedly this area has the potential to maintain and increase its position as the world's largest producer and exporter.

Based on this analysis it seems likely that the realization price range to justify new investment would have to be about $275-300 per metric ton of bagged urea.

5.0 PHOSPHATE FERTILIZERS

In order to assess the effect of energy and investment related costs on the total cost of producing phosphate fertilizers in the future in different locations, triple superphosphate has been used as a basis, as it is the major concentrated single nutrient phosphate fertilizer.

The production of triple superphosphate involves three main operations; the mining of phosphate rock, the production of sulphuric acid and phosphoric acid and finally the production of granular triple superphosphate from phosphate rock and phosphoric acid. Each of these operations has been considered over a range of investment costs likely to prevail at different locations, and the main components of production costs have been estimated for new plants that would come onstream in the mid-1980's. Finally the overall components of production costs have been estimated in order to assess the overall effect of capital related and energy costs on total production costs for triple superphosphate in a fully integrated project which includes the mine and process plants and the importation of elemental sulphur.

5.1 Mining of Phosphate Rock

5.1.1 Investment Costs

Mining and investment costs for phosphate rock can vary widely for different places and even within the same mine, depending on quality and on extraction of rock and other geological considerations such as nature and thickness of overburden etc. The overall production costs can also vary a great deal for different locations depending on infrastructural considerations such as rail and port facilities, fresh water availability, etc. For a good quality rock with simple beneficiation needs and high recovery rates the investment requirements can still be as low as $50 per annual ton of product capacity. For a new mine at a remote location where all infrastructure has to be provided, the cost of investment can rise to more than $200 per annual ton of product capacity.

The estimated components of production cost for mining a rock of good average quality in different locations is shown in Figure 4. It is assumed that the cost of rock in the ground is included as part of the initial investment cost and the mine has been depreciated over 20 years. The average cost figures used are based on a review of many mining operations in different countries and assume that open cast mining and wet beneficiation techniques are used. It is important however to appreciate that mining costs can vary widely - much more so perhaps than the chemical processing operations considered subsequently and so the figures used must be regarded mainly as average or typical costs essentially to demonstrate the relative effect of energy and capital related costs on total production costs.

5.1.2 Energy Costs

According to The Fertilizer Institute Survey, the average energy requirements for the unit operations used in phosphate rock mining in the U.S. are as follows:

Operation	Energy Required Million BTU per Metric Ton
Mining and Reclamation	0.29
Beneficiation (wet)	0.39
Rock Drying	0.44

Within the last three years, a great deal of information has been made available on the mining operations in Florida and elsewhere both from studies commissioned by the U.S. Bureau of Mines and also from several multi-client studies carried out by major consulting companies. In assessing the energy costs in Florida it has to be appreciated that this location is a relatively high level energy user. The average grade of ore mined in Florida is about 10% and recovery is about 60% whereas in many North African countries and also in Jordan the grade of ore as mined can fall in the range of 25-30% P_2O_5 and often only simple beneficiation operations, involving a low energy requirement, are needed.

The average energy consumption in the U.S. to produce one metric ton of rock varies from about 0.8 million BTU up to about 1.6 million BTU with an average of about 1.1 million BTU. As energy is mainly in the form of electric power and also because in most areas of the world where phosphate rock occurs, cheap gas is not normally available, an energy cost of $5.5 per million BTU is assumed. On this basis it is estimated that a typical cost of energy per metric ton of rock in the future will be about $6.0 of which about $2.0 is required to dry the rock.

5.1.3 Total Production Costs

Phosphate rock production costs for different locations and investment costs are given in Figure 4. Transport costs from the mine to the port are included both in the investment and operating costs and the results indicate a total production cost of between about $28 per ton on a developed site and up to about $60 per ton on a developing site. The most important component of cost is capital related which varies from about 40 to 70% of total production cost.

"Other Costs" which include labor and administration, chemicals, transport, etc. is the second most important component. Energy costs are significant but they normally amount to less than 20% of the total costs and are not therefore an overriding factor. If we assume for example that energy price increases in real terms by about 3-1/2% per annum in five years this would mean an increase in total production costs of less than $1.5 per ton of rock.

5.2 Phosphoric Acid

5.2.1 Investment Costs

The cost estimates are based on a phosphoric acid-sulphuric acid complex to produce 1,000 t.p.d. P_2O_5 as merchant grade acid. It is assumed however that the acid plants would be near the rock mine and that wet phosphate rock would be used. The complex would also include a totally integrated energy system. In order not to overestimate the cost of infrastructure, it is assumed that the main infrastructural facilities are included in the overall investment costs for phosphoric acid. The transfer price of wet rock for each scenario has been taken as $35 per ton of rock calculated on a dry basis. A conventional dihydrate process is considered in the assessment. The phosphoric acid plant on a developed site would apply mainly to Florida and to some locations in North Africa and elsewhere where there is already an established phosphate industry. Although the investment costs are presented in the form of investment cost per annual ton of P_2O_5 capacity, for a developed site and a 1,000 t.p.d. P_2O_5 plant, the actual investment cost is likely to fall in the range of $150-200 million, for a developing site about $200-250 million and above for $250 million for a remote location.

5.2.2 Energy Costs

The Fertilizer Institute Survey shows the following average energy usage for the manufacture of phosphoric acid in the U.S.

Operation	Energy Required Million BTU per Metric Ton of P_2O_5
Filter Grade Acid (from wet rock)	3.5
Concentration to Merchant Grade	5.9
	9.4

On average the average energy recovered from burning sulphur to produce sulphuric acid is 3.5 million BTU per ton of P_2O_5 produced. This means therefore that the average energy input per ton of P_2O_5 produced is 5.9 million BTU.

This energy requirement is very high taking into account the potential to recover heat from sulphuric acid manufacture and is due largely to the fact that because energy prices have been so low in the U.S., there has been little incentive to recover maximum heat during phosphoric acid production. Some plants in the U.S. however do reasonably well as can be seen from the lower interquartile T.F.I. figures.

Operation	Energy Required Million BTU per Metric Ton P_2O_5
Filter Grade Acid	2.5
Concentration to Merchant Grade	4.4
Energy Recovered	-5.7
Net Energy Required	1.2

In the cost estimates it is assumed that the energy consumption for new plants should not be in excess of about 2.5-3.0 million BTU which at present oil-equivalent energy prices of $5.5 per million BTU would result in an energy cost of $15 per ton of P_2O_5 when starting with wet rock and sulphur.

5.2.3 Total Production Costs

For a developed site the total production cost for phosphoric acid will be between about $420-470 per metric ton of P_2O_5. For developing sites the cost is much higher. The main component is the cost of the raw materials - phosphate rock and sulphur. Energy and other costs form a relatively small part of total cost - less than 5%. Capital related costs are a significant item particularly for developing sites and emphasize the advantage of building new plants on sites with existing infrastructure.

If energy costs increase at a rate of 3-1/2% per annum during the next five years it would only increase the cost of producing phosphoric acid by about three or four dollars. However there are certain developments now underway such as the increased use of the hemihydrate process, increased heat recovery from sulphuric acid production, etc. that could actually reduce or eliminate the energy required for phosphoric acid production.

5.3 Triple Superphosphate

It is assumed that the triple superphosphate plant is part of an integrated phosphate complex and the costs for TSP have been calculated on two bases. In the first, it is assumed that the starting materials are phosphoric acid and phosphate rock. As in the previous case for phosphoric acid the transfer price of rock has been taken as $35/ton. In the second case the overall production cost of phosphoric acid had been calculated by integrating the costs of phosphate rock, phosphoric acid and TSP production.

5.3.1 Investment Costs

The investment costs are based on a slurry granulation process with an output of 1,200 t.p.d. of granular TSP. The effect of location on investment cost is mainly covered in the transfer price of phosphoric acid so that the difference in investment for the three regions is due mainly to the additional storage and working capital needed on the developing sites. The cost of a large TSP plant with supporting facilities on a developed site would be about $35 million and with working capital at about $12 million the total investment would be equivalent to $120 per annual ton of capacity.

5.3.2 Energy Costs

The main energy costs for TSP production are for electricity for the granulation and drying plant and gas or fuel oil to dry the product. According to The Fertilizer Institute Survey, about 1.6 million BTU are required per metric ton TSP with an interquartile range of about 1.2-3 million BTU. For a new plant it has been assumed that 1.4 million BTU would be required equivalent to an energy cost of $8 of which about one-third would be required for electricity and the remainder as gas or oil for drying.

5.3.3 Production Costs

When considering the manufacture of TSP separately, the major cost of production is the cost of raw materials which comes to about 75% of total production costs. Capital related costs amount to about 15% and the remaining 10% or less is for energy and other costs such as labor and overheads. These costs are shown in Figure 6.

The costs of production when considering TSP in a completely integrated process with only the purchase of sulphur are shown in Figure 7. Investment per annual ton of capacity includes the cost of mining and producing both phosphoric acid and TSP. Overall the capital related costs vary from about 50-70% of total production costs, and energy costs are between 10-7%. The relatively low energy requirements to produce phosphate fertilizers is due mainly to the heat recovered when burning sulphur to produce sulphuric acid. The total heat released is equivalent to about 5 million BTU per ton of sulphuric acid or about 15 million BTU per ton of sulphur burned. This is roughly equivalent to about 0.3 tons of fuel oil. In practice not all of this heat is recovered and only about 40% recovery has been assumed in this paper. The total cost of energy to produce one ton of TSP is about $20 and if energy price increases by about 3-1/2% per annum for the next five years in real terms this would increase the cost of TSP by $4-5 per ton. However it seems likely that new plants will incorporate facilities for energy recovery that could compensate to a large extent the increasing energy prices.

6.0 POTASH FERTILIZERS

Like phosphate rock, the mining and beneficiation of potash varies significantly from location to location. However it seems likely that as most new capacity outside the Centrally Planned Economies will be developed in Canada, this location has been taken as a basis for estimating investment and production costs.

6.1 Investment Costs

Costs estimates are based on a mine in Canada using underground dry mining with conventional flotation and crystallizer scavenger circuits for beneficiation. The capacity of the mine is assumed to be 2 million tons of product per year. Although direct operating costs are relatively cheap in Canada, investment costs are rather high because of the difficult climatic conditions there. Although there is only limited information available on investment costs for potash in different locations, based on the information available for nitrogen and phosphate fertilizers a range of investment costs have been projected for different locations. It is assumed that Canada would come toward the higher range of investment costs for a developed site when considered as an ex-mine cost basis (about $300 per annual ton of capacity) but toward the center of the range for a developing one when account is taken of the cost and facilities required to transport the product to a port.

6.2 Energy Costs

The average energy consumption for potash by shaft mining in the U.S. according to The Fertilizer Institute Survey is:

Energy Required Million BTU per Metric Ton Product

Gas	Electricity	Total
1.36	1.06	2.4

These figures are higher than those reported for Canada but this is most likely due to the fact that the U.S. figures contain some plants with high energy usages. In Canada most new plants will use physical rather than thermal methods of beneficiating potash and will therefore require less energy on average. It has been assumed therefore that the energy usage per ton of potash product ex-mine is 1.8 million BTU. At $5.5 per million BTU this energy would cost about $10.

6.3 Total Production Costs

Total production costs including return on investment and interest charges for a new mine in Canada would fall in the range of $80-90/ton ex-mine and exclusive reserve taxes. Allowing a transport cost of around $30/ton this would give an f.o.b. total production cost of $110-120/ton. In terms of ex-mine costs, energy would amount to about 10% of total production costs assuming that energy costs rise to equivalent energy costs for oil. In fact in Canada as discussed earlier, gas prices are only likely to rise to about 65% of their value. Energy is therefore not likely to be an overriding factor in future potash costs or selling prices. Capital related costs will remain by far the most important component of production costs comprising on average about 70% of the total. The costs for potash are shown in Figure 8.

7.0 REFERENCES

1. Investment and Production Costs for Fertilizers. Paper presented to the FAO Commission for Fertilizers Sixth Session, Rome, Italy, July 1980 by W. F. Sheldrick, World Bank.

2. Energy Use Survey, CY1978. The Fertilizer Institute, United States, August 1980.

3. Perspectives on Natural Gas and LNG in the 1980's, Chemical Economy and Engineering Review 1980, Volume 12, No. 6, Japan, by Akinobu Tsumura.

FIGURE 1

THE EFFECT OF REDUCED PLANT UTILIZATION RELATED TO THE EQUIVALENT INCREASED COST OF GAS TO MAINTAIN SAME R.O.I.

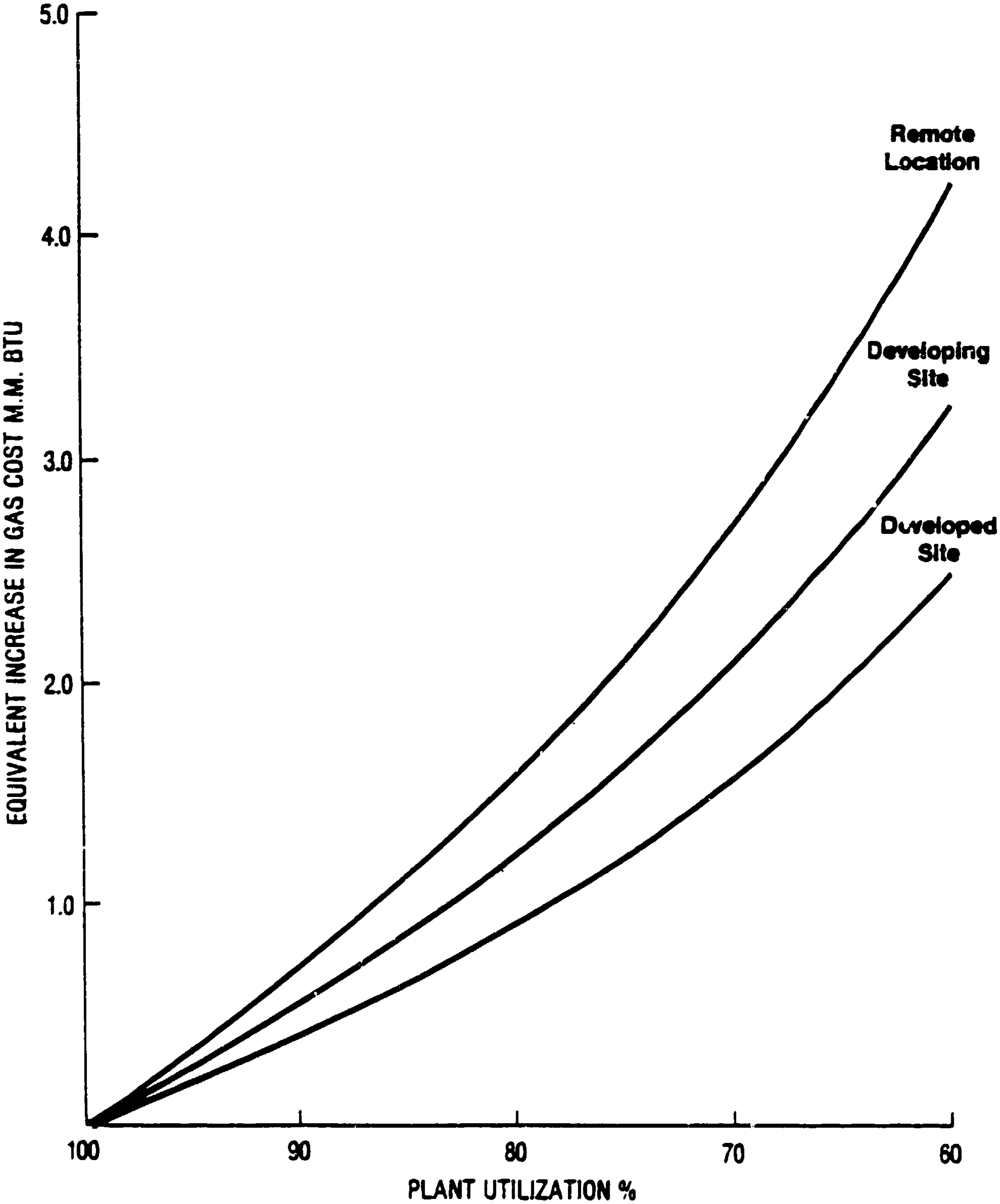

FIGURE 2

COST OF TRANSPORTING LIQUIFIED NATURAL GAS

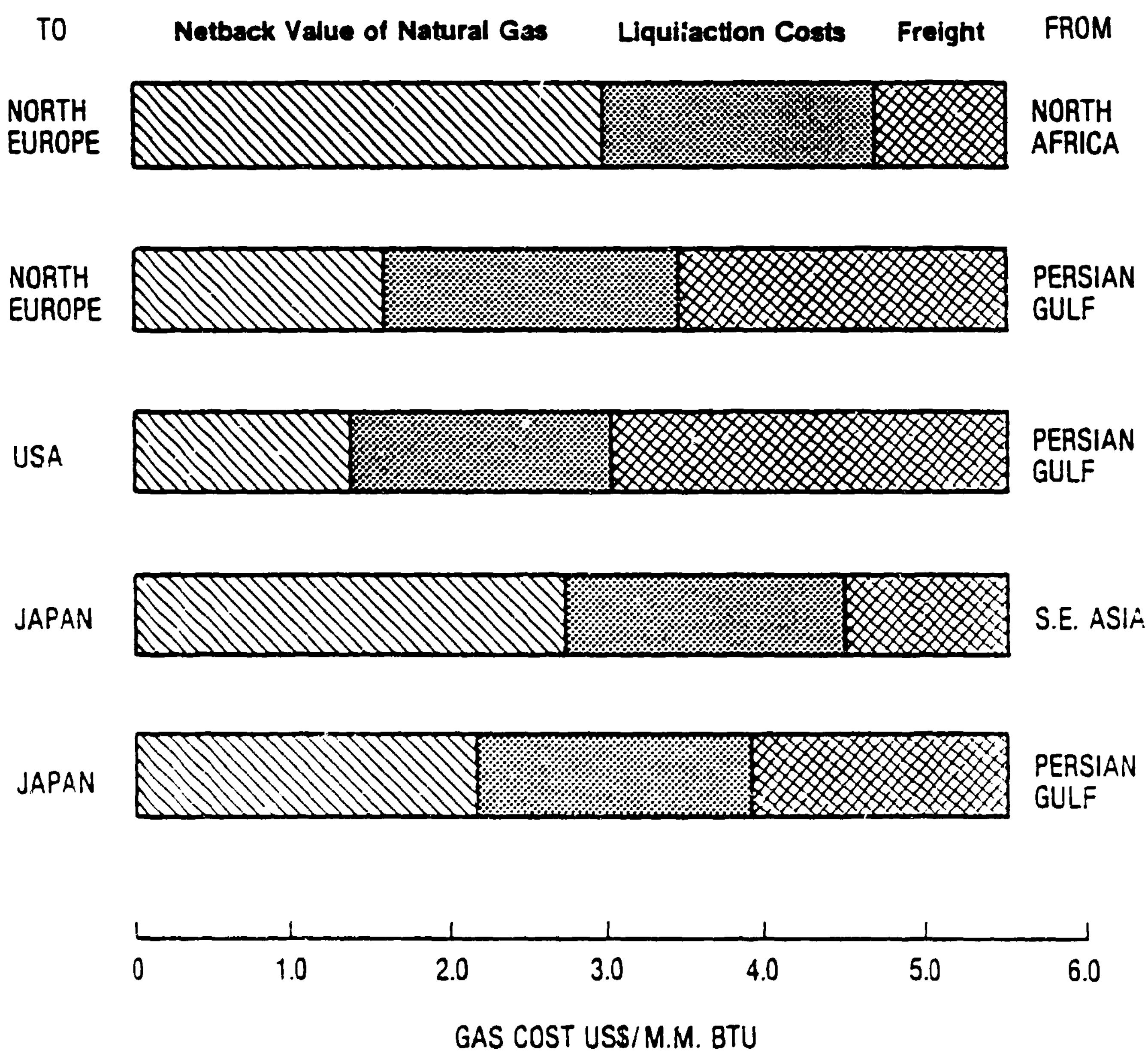

FIGURE 3

UREA PRODUCTION COSTS FOR DIFFERENT LOCATIONS, INVESTMENT COSTS AND ENERGY PRICES

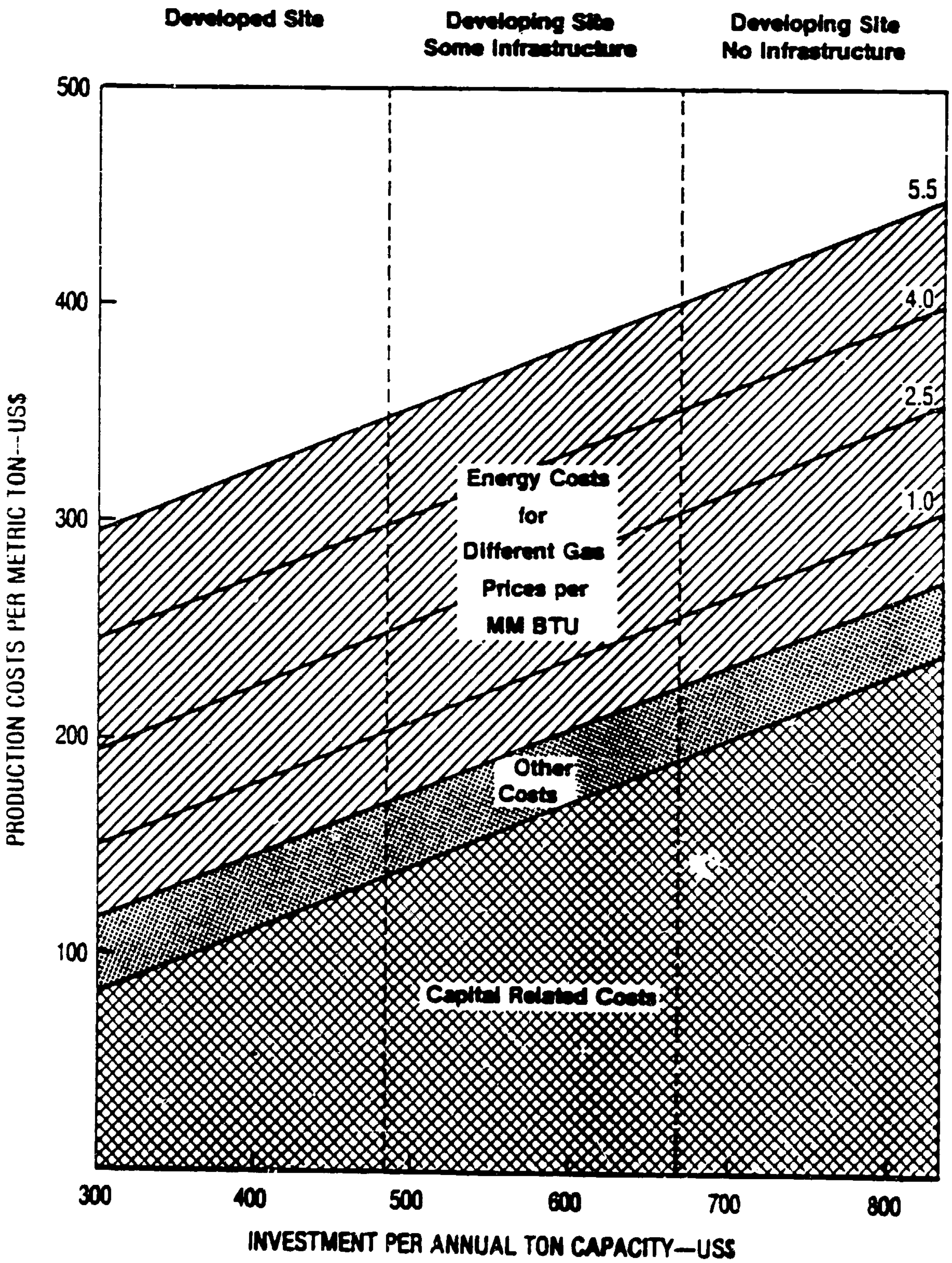

FIGURE 4

PHOSPHATE ROCK PRODUCTION COSTS FOR DIFFERENT LOCATIONS AND INVESTMENT COSTS

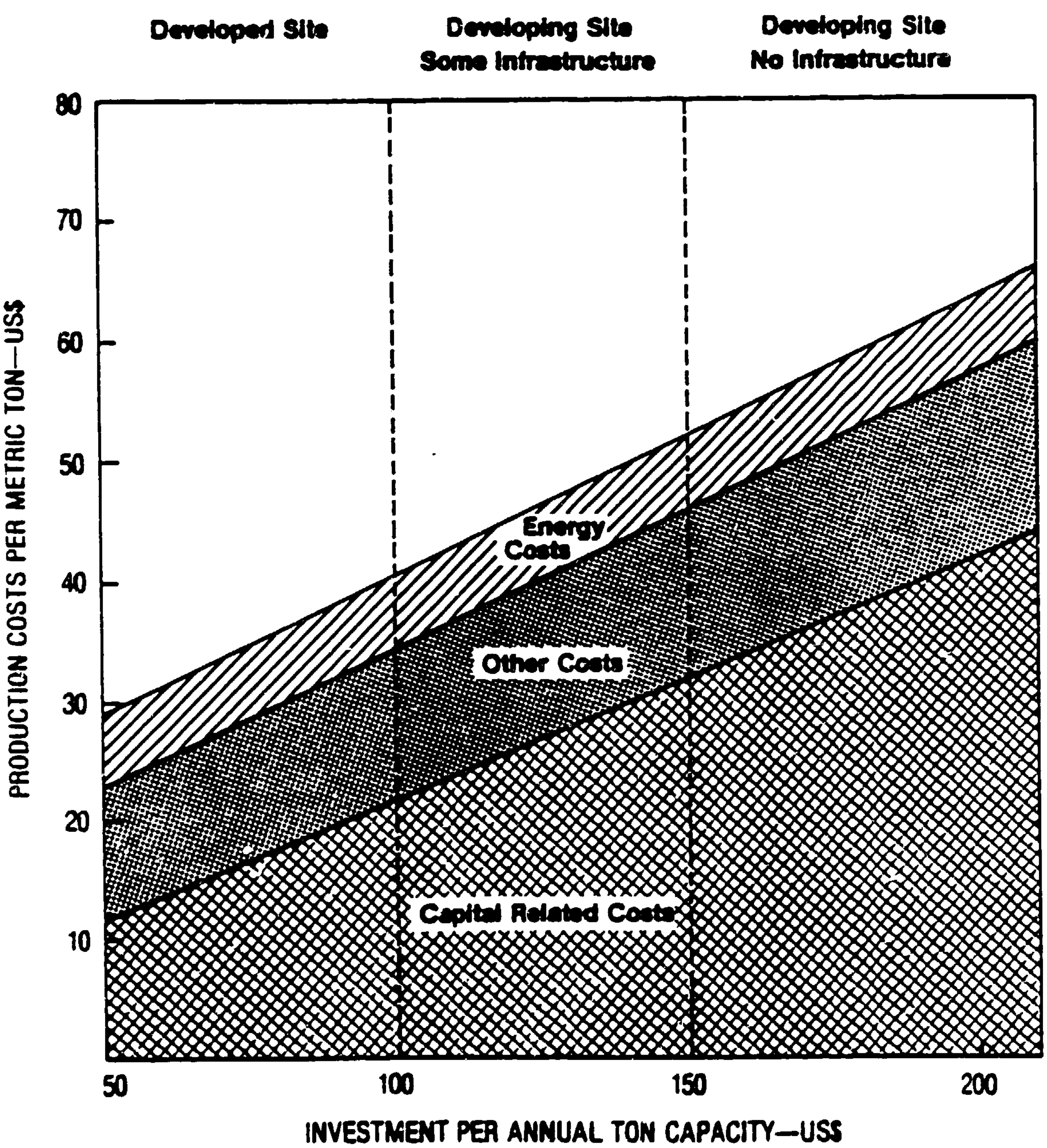

FIGURE 5

PHOSPHORIC ACID PRODUCTION COSTS FOR DIFFERENT LOCATIONS AND INVESTMENT COSTS

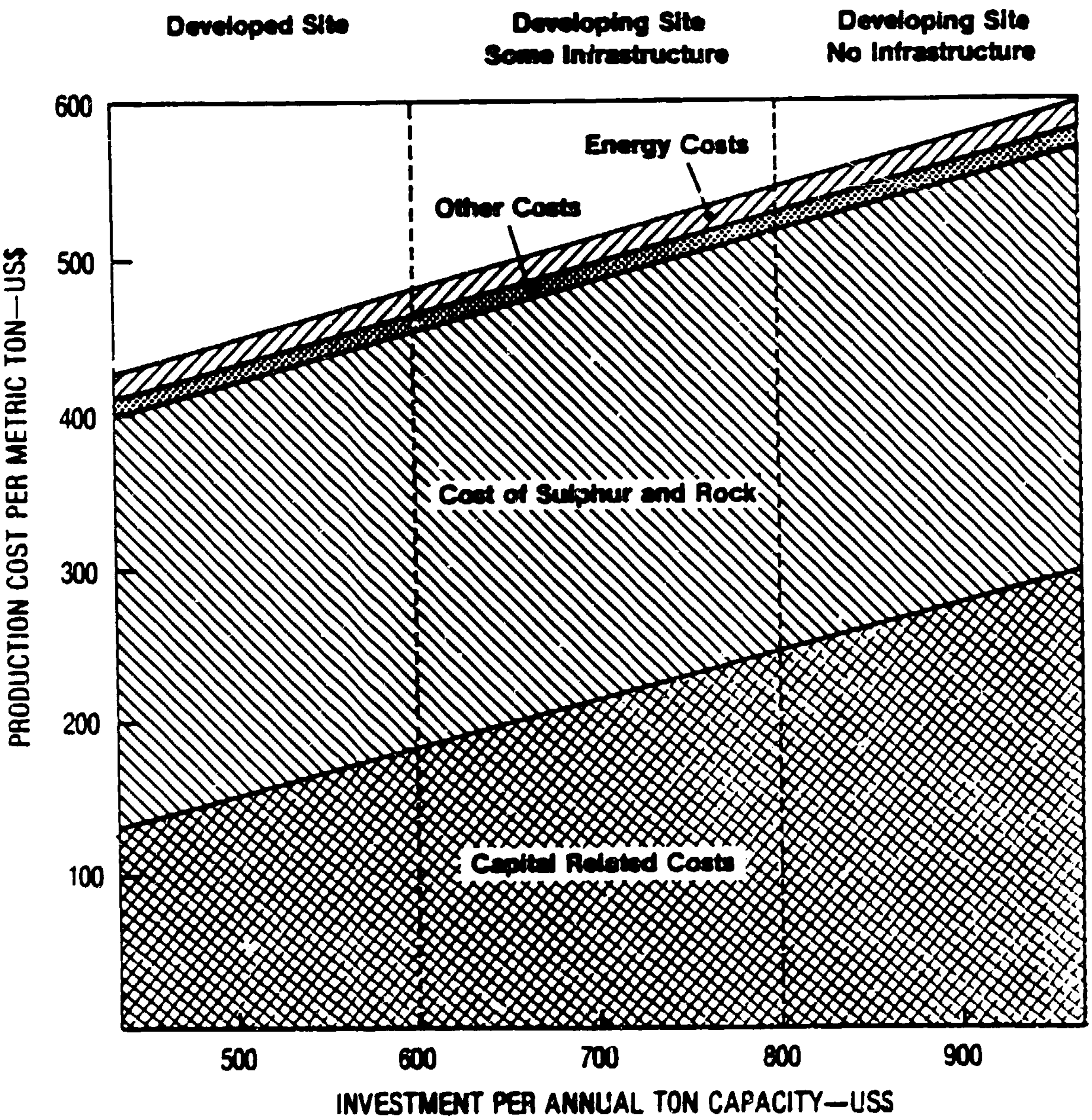

FIGURE 6

TRIPLE SUPERPHOSPHATE PRODUCTION COSTS FOR DIFFERENT LOCATIONS AND INVESTMENT COSTS

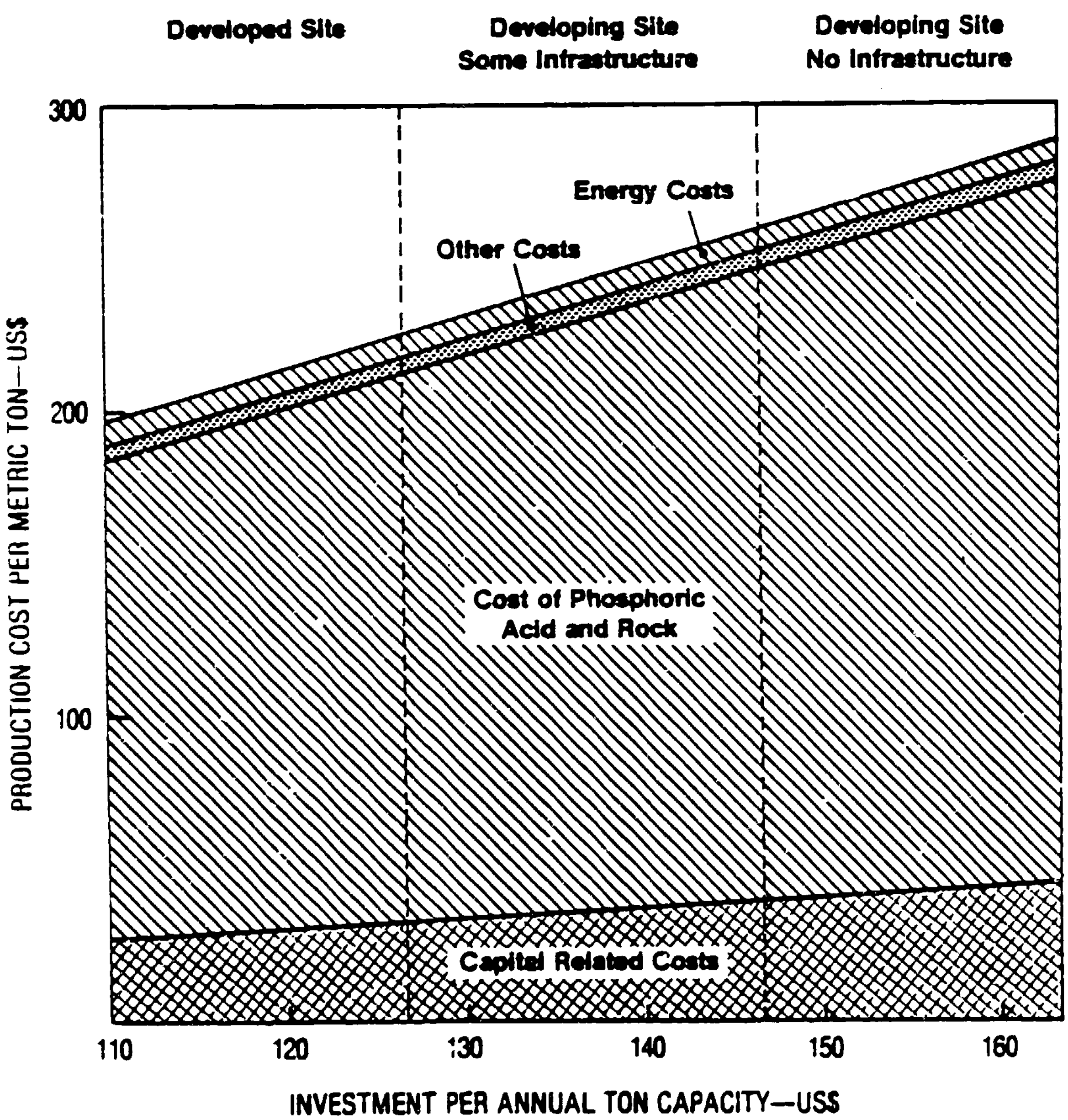

FIGURE 7

OVERALL PRODUCTION COSTS FOR TRIPLE SUPERPHOSPHATE INCLUDING ROCK AND PHOSPHORIC ACID FOR DIFFERENT LOCATIONS AND INVESTMENT COSTS

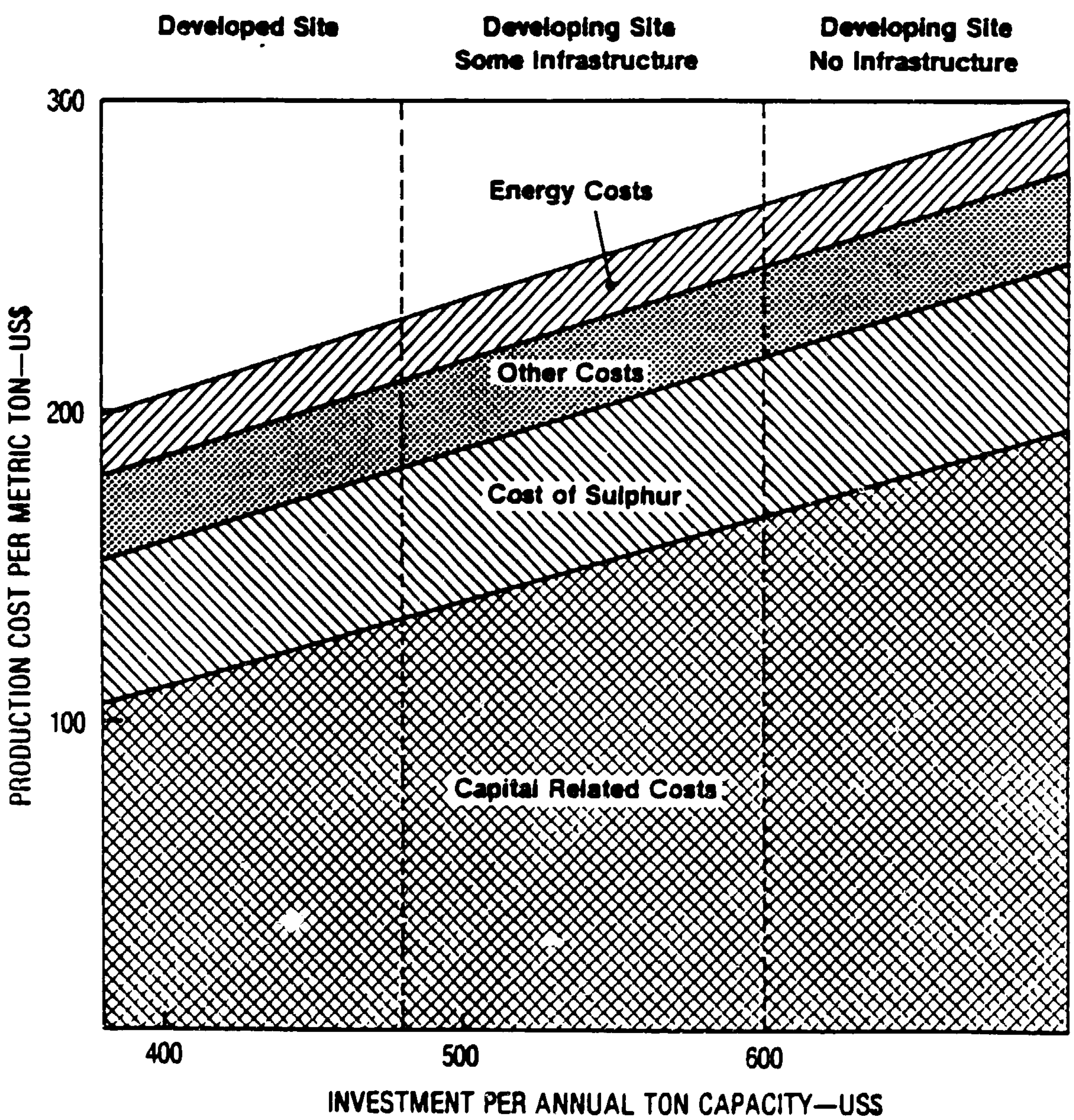

FIGURE 8

POTASH (60% K_2O) PRODUCTION COSTS FOR DIFFERENT LOCATIONS AND INVESTMENT COSTS