THE ECONOMICS OF METHANOL PRODUCTION IN NIGERIA BASED ON LARGE LOW-COST GAS RESOURCES

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I. PURPOSE

The purpose of this study is to place methanol in perspective as a potential user of natural gas in Nigeria. Methanol production ranks third in the world after LNG and Ammonia/Urea among large gas uses other than putting gas in pipelines to reach various markets. If gas can be pipelined to market, normally this is the most cost effective outlet. Two critical issues to consider in determining cost effectiveness are reasonable pipeline distance and a terrain that does not make pipeline construction costs prohibitive. A third issue on the horizon is pipeline security.

In this presentation we do not advocate a particular project but, instead, we cover the scope of possible methanol projects ranging from a 100-ton per day market development plant (the HydroChem option) to a 10,000-ton per day methanol-power-cogeneration plant, which today is technically feasible but not yet planned for actual projects. Between these two projects, the small and the large, are the existing 2500-ton per day plant units and the now favored 5000-ton per day plant that uses advanced but well proven technology. One of these large plants is under construction and one is slated to enter construction shortly. Several others are in planning or engineering stages.

We do address here a specific end use project, namely, a fuel-methanol market development project, and we also discuss other potential fuel uses of methanol to illustrate how much more methanol capacity would be needed if these very large fuel markets were developed for methanol at even modest market penetrations.

II. BACKGROUND

A. Historical

The methanol industry is over a century old. Its history divides into roughly four eras. In the first, 1850 to 1920, methanol was made as a by-product of wood carbonization to make various wood-derived chemicals, with charcoal as a by-product. In the second era, in the mid-1920s, the high-pressure synthesis of methanol from coal-derived gas (CO and H_2) was discovered. Part way through this era, feed stock shifted from coal-derived synthesis gas to that made from cheap natural gas, with a consequent drastic reduction in manufacturing cost and a lowering of capital cost.

The third era, starting mid-Twentieth Century, was ushered in by the low-pressure process reducing pressures from roughly 5000 psig to about 1000 psig. Plants became larger, capital costs came down and so did manufacturing costs. During this era plant sizes were constantly increased and a standard of about 2500 tons per day for a single line was finally reached.

Late in this period there developed a frenzy of effort to reduce the capital cost of plants by innovations in synthesis gas production, an effort that carried forward strongly into the next era.

The fourth era, in which we are now, started near the end of the century and might be called the mega-plant era. During this era, every effort has been made to gain the economics of scale by going to 5000 tons per day per line or even larger. Efforts to reduce capital in the synthesis gas end of production have accelerated. This era will see continued changes. The first 5000-ton per day lines are not yet on stream but one is about halfway through construction and several others are at various stages of planning and/or engineering. We can project the economics of these new plants but we have yet to realize them.

On the horizon, in our opinion, is yet another era in which two things will happen:

(1) Major markets for methanol for energy uses will finally open up, after over 30 years of discussion and preliminary effort,

(2) We will see the advent of methanol/electrical-energy cogeneration plants. Already some large methanol plants have power to export. Synergisms exist between methanol production and power production. The famous Cool Water integrated coal gasification and combined cycle project looked at the concept of making and storing methanol when all of the gas was not needed for power. Another variant is integrations of gas reforming and combined cycle power generation that makes fuel grade methanol of slightly less purity than chemical grade methanol. Such a plant has yet to be built but all of the technology is proven and the necessary power generation equipment is available from General Electric.

The main reason we stress this history is to show that methanol technology is still undergoing constant improvement with a result of continued cost reduction of methanol. This includes increasing line size, improving reforming to reduce capital and oxygen use (when combined reforming is used) and generally to reduce capital cost and overall production cost. In some cases CO_2 emissions per unit of product can be reduced.

The goal of advanced methanol process-engineering designers is to bring the delivered-to-terminal cost of methanol on a Btu basis down to the level of LNG or below it. Some such designs have already been published. [1]

The Btu costs referred to are delivered to a terminal. What is important in the final analysis is the Btu cost *delivered* to the customer. Here it must be remembered that the distributor can take methanol from a low-cost terminal with a gasoline truck and the consumer can take it away in a jerry can. LNG, held in a much more expensive terminal, must be regasified and delivered by pipeline to a large customer or a large group of customers whose consumption can justify the line, which itself will cost up to 1 million dollars per mile depending upon size and terrain.

What this brief excursion through history tells us is that we can start with raw material Btus, costing generally $0.25 to $1.0 per million, convert them to an easily transported liquid fuel, transport that fuel to market, have a highly superior fuel, always exactly the same because it is made of a single molecule, ***and do this today at a profit, for a cost of about $4.6 per MM Btu***.

[1] Toyo Engineering Corporation (TEC)

Crude oil, when delivered at $25 per barrel, and which has to be further refined, represents in its finished fuels a raw material cost above $4.8 per MM Btu even before O&M costs or capital charges on the refinery are considered.

On the horizon, waiting only for application, is proven technology that can reduce the delivered MM Btu level for methanol to about $3.7. If combined with electrical energy production in even larger plants, the level could approach $2.8 per MM Btu.

However, new markets must be developed on today's level of cost, which, over the years, has averaged $6.2 ± 1.5 per MM Btu with occasional distress pricing as low as $4.1 per MM Btu, the latter representing cost plus some return for the larger plants with cheap gas.

The general direction of crude oil price is up, whereas most of the world's natural gas is priced independently of crude oil because otherwise it simply would not get to market. The resource base for gas is at least as large as for conventional crude oil and some analysts are saying that the gas reserves are much larger, *not counting* such vast sources as methane hydrates.

Were methanol to compete with gasoline for transport fuel or with kerosene when used for domestic fuel, the respective retail price levels would be, before taxes, about $7.0 per MM Btus for the gasoline market (which has efficient distribution) and $7.4 to $11 per MM Btu for the kerosene market (which has a less efficient distribution system).

With the more efficient existing methanol plants able to stay in business at about $4 per MM Btus delivered to terminals, and tomorrow's plants able to push consistently below $4 per barrel, the opportunity for methanol as a fuel is apparent, especially when it is considered that methanol, for certain uses, has premium properties justifying a higher Btu cost than petroleum fuels.

B. Commercial Considerations

Today, world methanol consumption for chemical uses is about 30 million tons per year, using gas at the rate of 1 TCF per year or nearly 3 billion SCFD (78 million SCMD).

In a country such as Nigeria, if a world-scale methanol plant were built, it would probably be at least 5000 tons per day in order to take advantage of the well-known effect of scale in lowering capital cost per unit of output. Such a plant would use roughly 170 million SCFD (4.8 million SCMD). It would employ about 50 people directly in the plant, not counting employment for methanol sales and distribution. At the time of construction, there could be 200-300 people employed. In downstream chemical uses such as formaldehyde, acetic acid and a myriad of other uses, wealth creation and employment could be ten-fold that of methanol production, if not more.

C. Mega Methanol Plants

These are the plants now being built. The first such plant will cost about $400-450 million, battery limits. Since a large methanol plant generates all of its own power and may even have some excess power to sell, the off-site infrastructure requirements are minimal unless extensive marine work is required to create a deep water loading dock and all that goes with it. An allowance of 15% for normal off-site work on the first unit is reasonable but in the example that follows, we use 25%, on the assumption that marine work will be required.

The second unit, when built, adds very little in the way of off-site costs.

Such a plant would initially have to be primarily for the export market, but in Nigeria, for example, the domestic fuel potential alone is more than large enough to support such a plant in the long run.

D. Small Plants

If there is a small, targeted market for methanol in a given country, far smaller than would justify a large plant, or (as in the case of our project, *Project Gaia*), it is desired to demonstrate the feasibility of methanol production using flare gas, and to develop an entirely new market such as the domestic fuel market, then a pre-fabricated modular methanol plant can be procured and shipped in on skids. Such a plant would typically be 100 tons/day because of the slightly better economics, but there are few technical limitations to it being 50 tons/day or even 10 tons/day. Its gas consumption per unit of output would be higher by 10-30% than a large plant, but with cheap gas, this would be of little consequence to the economics. The design philosophy in this case is to minimize capital cost at the expense of efficiency. Fortunately, the designer of such plants, HydroChem, Inc., is able to rely on many decades of building skid-mounted hydrogen plants that already embody all of the costly and difficult parts of a methanol plant, which account for 60% or more of the total cost.

E. Economic Generalizations

In countries with ample and inexpensive gas, capital charges on large plants, as with LNG and ammonia plants, dominate the required selling price of the product. The other important item in selling price is shipping cost to reach the market. This alone may be as much as plant O&M costs, excluding the raw material purchase.

In the case of small package plants, capital charges are even more significant, but in this case purchased power may be the next largest cost if power rates are high. They are frequently around 8 cents/kWh in developing countries. Also, reliability of purchased power may be low so that adding gas-engine-driven generators may be necessary and indeed very cost effective even though they raise the capital cost.

Obviously, the small plant must be financed very favorably if it is to produce methanol at a cost roughly competitive with the cost of imported methanol. Even so, the smaller plant can never quite match costs with a large plant even though the latter is financed on a higher return basis. ***But once the small plant has paid off its debt, it may survive even in competition with the large plant, particularly if it is located closer to its market than the large plant so that it can enjoy some freight savings.***

The thermal efficiency of a large plant, when trade-offs between capital and raw material are optimized, is about 65%, based on higher heating value. Seventy percent would push the limit. An LNG plant is about 90% efficient but its initial size has to be two to four times as large as a methanol plant to be in the most economic range.

What has not yet been exploited in the methanol industry is the concept of a cogeneration plant, such as Foster Wheeler proposes and is ready to build. ***If electrical energy can be sold to a grid at about 6 cents per kWh or more, this integration should be embraced in a country such as Nigeria.***

Today, methanol tends to be market limited because it is marketed for chemical uses only. However, even the smallest penetration into power generation uses would catapult the methanol industry to two, three, or even ten times its present size. One cannot economically transport LNG to the interior of Nigeria, but methanol is as easy to transport, like gasoline. At the plant gate, methanol can be sold for about $4 per MM Btu. Distillate fuels made from premium Nigerian crude at $25/bbl start out with a raw material cost of about $4.3 per MM Btu. Refinery efficiency (about 90%) and capital charges, plus O&M on the refinery, boost this to $5.2 for an existing refinery, or to about $6.0 for a new refinery operated to pay back debt capital and pay return on equity in the same manner as the methanol project. (The $6.0 figure may in fact be too low to cover the new refinery case where environmental restrictions are tight.)

The attributes of the methanol for fuel cell use or use in gas turbine power units is superb. It has zero-sulfur emissions and burns with only 5 ppm of NO_X. It reforms to hydrogen in a reformer-type fuel cell very easily, far easier than natural gas or liquid hydrocarbon can be reformed to hydrogen.

Thus, in a developing country anxious to extend low-cost energy out to the rural populations, fuel methanol could be an excellent choice both for distributed power generation and domestic cooking, and for other uses as well. In the U.S. or Europe, with gas pipelines everywhere, fuel methanol is a good choice only where it offers extra advantages such as supply for the fuel cell automobile.

If, for example, a combined cycle power plant were built to serve Abuja where it could be operated as combined heat and power (CHP), and if the methanol delivered cost were $5.5 per MM Btu and the CHP efficiency were 80%, then the cost of methanol per kWh would be 2.3 cents per kWh. The capital charges, if we take a typical $600/kW capital charge and a 60% load factor, would be only about 1.5 cents per kWh. If one adds 0.5 for O&M (high), the total at the bus bar would be 4.3 cents/kWh. There would be zero pollution and a relatively low CO_2 per kWh. The recovered waste heat could be used to produce chilled water for air conditioning hospitals, offices and government buildings.

What this power generation example amounts to is a way to transport gas to Abuja without a pipeline. Methanol is an economical energy carrier.

As suggested above, the unappreciated or underestimated opportunity for a country like Nigeria is to cogenerate power *and* methanol. This offers the best opportunity of all to bring methanol into competition with LNG for the export market. This technology is ready and is offered by Foster Wheeler as its ***Starchem Process***.[2] All of the process steps are proven in other uses whether in the methanol or in the power generation industries. Foster Wheeler is confident that it can reach a plant-gate-selling price of $60 per ton (18 cents per gallon or 4.8 cents per liter). Even if we put a +15% on this estimate, it is still an extremely low price.

When one sums up the arguments for methanol production in Nigeria, the conclusion is, it is not whether but only when.

[2] Foster Wheeler

III. TYPICAL METHANOL ECONOMICS

A. Large Plants

Several 5000 tpd units are now being built. These plants will set the best economic performance possible to date. However, technology suppliers are talking about even lower plant gate prices (with return) in the future based on technology already developed and ready to be used in such plants.

For example, Haldor Topsoe [3] is projecting these kinds of plant gate prices:

Table I
Haldor Topsoe Methanol Price Projections
Plant Gate Price, $/MT

	Current World Scale	Auto thermal reforming	Pre-reformer and advanced auto-thermal reforming
Plant gate Price with 15% IRR	105.00	83.00	70.00
$/MM Btu HHV	4.8	3.8	3.2

Current world scale (column 1) refers to plants with 2500-2700 tpd trains, not 5000 tpd. To reach the market, freight adds to these prices $15/ton today and $12 per ton in the future. The corresponding delivered prices would be $120, $95 and $82 respectively. The last price would be $3.8 per MM Btu.

If we look at the probable ex-plant selling price for the 5000-ton per day plants being built now and with 25-cent gas (to represent a distress gas price where flaring is occurring), the economics at capacity are detailed below. For a large plant, we assume no preferred financing by World Bank but commercial financing rates of 70% debt payable over 10 years at 8% and 20% before tax on equity where there are no taxes for 10 years as plant depreciation shelters book profit.

[3] Haldor Topsoe paper at CMAI World Methanol Conference in San Diego, CA, 1999

Table II
Projected Plant Price for Current 5000 tpd Plants Under Construction

Capital

Battery limits	($233/annual ton)	$384,000,000
Off Sites	(58/annual ton)	96,000,000
Total	($291/annual ton)	$480,000,000

Plant Price	$/ton	¢/gal	¢/liter
Capital charge	50.6	15.2	4.0
Feed and Fuel	8.3	2.5	0.66
Plant operating and Maintenance	16.7	5.0	1.32
Selling & Admin	1.7	0.5	.13
Total Plant Price	77.3	23.2	6.11

This plant price assumes 330 days per year operation at full capacity. A more likely scenario would be 80% of this amount. This raises the plant price to $94 per ton (28 cents/gal, or 7.4 cents/liter).

If we look back at Haldor Topsoe's current world scale at $105 per ton and compare this to $77, it gives an idea of the improvement that the latest world-scale technology can make.

This presentation is obviously not intended to be investment grade economics for a given project. It is simply to show the general price level that can be reached and to indicate where the largest cost factors are. However, the cost figures are well within a ± 15% range.

Were such a plant located in Delta State, it could deliver bulk methanol 400 miles to Plateau State, for example, for about 10 cents per gallon. If we add this to the 28 cents/gal (above), it yields 38 cents/gallon delivered in bulk, or 10 cents per liter. These are, of course, figures that represent a very large scale of operation after experience has minimized costs. Even then, we may be somewhat optimistic. However, if–to be conservative–we assume 12 cents per liter delivered, and an eventual retail price of 25 cents (which, let us say, includes an allowance of 2 cents to subsidize the cost of methanol stoves to the consumer), then ***the net retail dealer spread is 23 -12 = 11 cents per liter or 42 cents per gallon, far above the typical dealer spread for gasoline (by 4 or 5 times), even, for example, in a high labor cost area like the US.***

Thus, there is little doubt that clean burning, easy to use methanol can one day be a very low cost fuel for millions of families now using inferior, polluting fuels.

Obviously such a plant as the one discussed above would be very competitive in the world market, where the average price realized over many years for chemical uses has been about 40 ± 5 cents per gallon ($133 ± 17 per ton) delivered to major ports with distress spot prices as low as 27 cents per gallon (90 per ton) and with the occasional high spot price range up around $200 per ton. Contract prices vary in a narrower range. As long as methanol is produced only for the chemical market, this kind of pricing will prevail. Were methanol to enter the fuel market in a large way, the pricing would more closely approximate the economies of large-scale plants.

The total use of methanol today is equivalent to about 0.7 quads. World petroleum use is about 163 quads and natural gas use, including flaring, is comparable to petroleum. LNG production is about 100 million tons per year, equivalent to about 240 million tons of methanol in fuel value, or slightly over 5 quads.

In Nigeria, assuming an average family size of five people, there are some 26 million families. If half of these families used methanol for cooking, about 3.8 million tons of methanol or the equivalent of slightly more than the output of two 5000-tpd plants would be consumed.

If, in the region of the nation's capital, Abuja, there were installed 2000 MW of combined cycle power based on methanol, the methanol use for this facility at 60% load factor would be equivalent to two 5000-tpd methanol plants built in Nigeria's gas fields.

When Nigeria’s economy is developed to its full potential, another 5000-tpd plant would be needed to supply chemical uses, if methanol use per capita were to reach even one-half of what it is today in the U.S.

In summary, this discussion shows that if Nigeria, as a prime example of a developing country with cheap gas resources, were to develop the full potential for methanol within the country and for export, it would create a very large industry, which would upgrade (or turn into value) a very large amount of gas.

B. Small Plants

1. General considerations

The question might be asked, “How can small plants, in view of the 0.67 scale (capacity) factor, ever compete?” If a 5000-tpd plant is to cost $400 million battery limits, a 100-tpd plant would then cost $\$400{,}000{,}000 \div (50)^{0.67}$ or $29,000,000. The answer is that factory fabrication of modularized small plants can greatly reduce costs per unit of output. This has been proven over and over again by small modular hydrogen plants, NGL plants and even simple refineries. Such plants are built to supply small, localized needs, especially in remote areas in developed or developing countries. The U.S. leads the world in this art and exports such plants to countries all around the world.

2. Why a small methanol plant in Nigeria?

It usually requires 5-8 years to conceive, develop, finance, permit, construct and start up a world scale methanol plant in a developing country where no such plant has existed before, and thus where there is not the opportunity to add an incremental unit. In the incremental unit case, a new plant can be planned and put on stream in 3 years or even less.

The markets for methanol in Nigeria are at this time scarcely developed and are based on imports. Reliable figures on current methanol use in Nigeria are hard to obtain, but demand appears to be less than 10,000 tons per year, and possibly well under this.

There is no formaldehyde production and yet there is significant plywood, particleboard and strand board industry in Nigeria. Formaldehyde is being imported at very high cost to make the adhesives for this industry.

To develop the domestic fuel use of methanol, the building of a small plant to produce methanol from wasted gas would attract much interest and, in turn, would serve to attract investors into this market.

A small package methanol plant could incorporate a package formaldehyde unit, which is an even easier and simpler process than methanol. If 100,000 methanol stoves were successfully placed into use, they would require 30,000 tons of methanol per year, or the output of a 100-tpd plant.

A reasonable approach, therefore, would be to develop a 100-tpd methanol pilot project, with World Bank (or other) assistance to obtain financing in order to demonstrate a market potential and to do it on a commercial basis that would allow payback of the debt with interest.

3. The economics of small methanol plants in a developing country with low cost gas

The capital cost of the first 100-tpd modular methanol plant, including erection, site work and off-sites in Nigeria, is estimated to be about $17,000,000, or $18,000,000 if power generation is included, which is the most realistic case. This is only about 60% of the scale down price from a large plant.

The second, third and successive identical plants would come down in price to 90%, 85%, and 80% thereafter. These are obviously not precise estimates, but are a reflection of experience with replication of modular plants.

We will illustrate the economics with $18,000,000 for a 100-tpd plant operated at 82% (300 days) operating factor. Since capital charges will dominate and since we cannot reduce capital costs further, obviously we must have favorable financing on a first plant to reduce unit capital charge. Therefore, let us assume World Bank financing on 70% of the debt over 15 years at 8%, or a yearly capital charge factor of 0.132. A large plant might be financed 70% debt over 7 years at 10% with a capital charge factor of 0.234.

The capital cost per annual gallon of the small plant is $1.8 while that of the large plant $0.87. Capital charges per gallon are then:

Small plant (0.132)(1.8) = $0.24 per gallon
Large plant (0.234)(0.87) = $0.20 per gallon

Thus, the financing method can almost equate the two capital charges per unit of product.

The other cost factors that can help the small plant are, first, to lower its gas price to not over 25 cents per MM Btu, or to make it zero for a period of time, and, second, to realize a savings from lower labor costs. Labor costs per unit are lowered by the differences in wage and salary costs between Nigeria and most developed countries where methanol is produced.

Based on these considerations, we cast the economics of a 100-tpd plant as follows:

	¢/gal	¢/liter	$/ton
Plant salaries, wages and overhead	2.0		
feed and fuel for power at 25 cents per MM Btu	3.1		
Purchased power	.1		
Catalyst and chemicals	.9		
Maintenance on plant and engines	4.9		
Raw water	0.1		
Insurance and taxes	1.7		
	12.8	3.4	
Capital charges	23.8	6.3	
	+36.6	9.7	122

While this result is very gratifying in view of world-delivered prices that have averaged about 40 ± 5 cents per gallon over the years, this result is at 100% plant capacity, 300 days per year. Of the total cost of sales, all but about 5 cents can be considered fixed. At 80% capacity, the selling price has to be (36.6 – 5)/0.8 + 5 = 45 cents (rounded). At half capacity, the figure is 68 cents per gallon or 17 cents per liter. Still, during market development, if retail price of methanol is held at 33 cents after netting out 2 cents for stove payments, this leaves 15 cents per liter for distribution from the plant to the retail dealer's counter.

The longer view is to look 15 years ahead with no debt and plant at 100% capacity. Then, with the 20% return on 30% original equity, the plant price could be 23 cents, if gas price remains the same, or 26 cents if gas doubles. Small plants, once debt is paid, can be economical if gas is cheap.

Since it will take 8 years or more for any investor to bring a large plant on line, half of the debt would be paid on the small plant by that time. Therefore, by then, the small plant would have long since reached capacity and lowest costs.

Another reason for starting small, other than market limitations, may be a capital limitation, which might apply in Nigeria.

C. Conclusions on Methanol Economics

Short term "in sight" (2-3 years) prices for methanol from small package plants built in Nigeria will be in the range of 40 to 70 cents per gallon, depending upon plant operating factor and rounding estimates such as 36.6 cents to 40 cents. This range would allow capture of all present and easily developed Nigerian chemical and solvent markets. A market to be developed, for example, is formaldehyde, the largest single chemical use of methanol.

This price range would also allow development of a domestic fuel market.

In sight from world scale plants in Nigeria are prices well below the historical 40 ± 5 cents per gallon delivered-average-price, e.g., delivered export prices as low as 30-35 cents at full project debt service and equity return. Such prices would be highly competitive in world markets.

The market awaits two events for the coming of the new era of fuel methanol:

(1) the shut down of high-gas-cost plants in the U.S., Canada and Europe, with adequate capacity built for cheap gas, and

(2) a new methanol company or companies that understand the fuel market and what is required to compete in it.

Fuel methanol for power generation will not tolerate high prices. Fuel methanol for domestic use will be more flexible in the pricing that it can bear.

Neither of the above two conditions exists today. The first is perhaps still 5 to 8 years away. The second may not happen for some time. It would appear that the existing methanol companies are not ready to enter the fuel methanol market.

IV. THE MARKET WINDOW OF OPPORTUNITY FOR A LARGE PLANT

The world methanol industry must eventually reconcile to reality: plants paying $3.50 ± 0.5 for gas cannot compete with those paying $0.50 to 0.80, with a few paying less and a few paying up to $1.0. In times of product scarcity, the high-gas-cost plants effectively place a high price floor on methanol, which is thoroughly exploited by the industry. At this floor price, the low-gas-cost plants make excessive profit, which they do not spend on efforts to create new markets. As long as the industry can keep the older high-gas-cost plants on stream, the more money the industry will make.

The industry appears to keep its expansion carefully in line with chemical market growth, which averages 3-4% per year, probably heading for 3% per year in the future due to the loss of the dynamic MTBE market. Even so, 3% represents one older world-scale plant per year or one newer sized plant (5000 tons per day) every two years. Today there are only about three such plants either under construction or under consideration. Since these plants require 3-5 years to actually happen, the new construction is more or less balanced with demand to keep the high-gas-cost plants running. Proof of this is today's spot methanol price, which is about 60 to 65 cents per gallon or $200-215 per ton delivered to major ports. This is nearly double what it takes to finance a brand new plant.

But as gas prices continue to rise (the trend is at least 4% per year in the U.S. and Canada), it is only a question of time until the opportunity becomes so great that a flood of new 5000-tpd plants will be started. If the timing on these new starts is wrong, methanol prices will peak very high or will temporarily go down to $90-100 per ton again.

Careful analysis of world production and demand, as well as of new plant trends, suggests that the window of opportunity will open wide for one or more new 5000-tpd plants in 5-8 years, about the period required to consummate a grass-roots project in a new location.

Where will such plants go? There is a large gas supply in the Middle East but also much risk. The same might be said of North Africa. Australian gas will not be inexpensive. Chile does not have enough gas. Trinidad gas is no longer inexpensive. Venezuela is rich in gas but plagued with political problems. An Alaska North Slope plant will not be a low-gas-cost plant on a delivered price basis.

It is a virtual certainty that one or more new plants will be constructed in West Africa where a low-cost world-scale methanol plant already exists. This is not difficult to deduce. The only factor for delay will be the investor's view of West African nations, and particularly Nigeria, as risk-tolerant investment opportunities.

Before a potential investor accepts our conclusions, he/she will want to have in hand a detailed study of the status of the existing plants and reliable intelligence on plans for future plants. There are well-qualified consulting groups to complete such an assignment. The cost of this type of detailed planning study ranges from $50,000 to $200,000. Even the latter figure is only about 0.04% of the cost of a new 5000-tpd plant, and should be considered a prudent cost to assure success.

V. CONCLUSION

As we said earlier, it is not a question of whether there will be substantial methanol production in Nigeria but only when. We would place the advent of methanol production in Nigeria at five years at the earliest and almost certainly within eight years.

If, on the other hand, there is a sufficient small market right now for methanol in Nigeria, then there is an excellent opportunity for one or more small (100-ton per day) package plants, which could be on stream in as little as two years and certainly in three years. Such small plants could enjoy a protected market for a sufficient number of years to get debt service down and operating factor and economy of operation up. Small plant survival could easily be 10 or15 years until the world methanol market finally reconciles itself around a very low-cost fuel market and is therefore no longer protected in price by high cost U.S. and European plants.

The requirement on the small plant is that it must have favored financing and low gas cost.

The fuel methanol market for power generation and motor fuels may belong in the hands of the major petroleum companies, possibly with some government participation. The petroleum companies have the gas with which to make the methanol, large capital resources, technical staffs and the fuel distribution system that is needed. They also are most knowledgeable in the chemical markets and, therefore, control most of the basic organic chemical production in the world. Such companies are not normally interested in small ventures. Thus, the small methanol plant probably belongs with government or with local entrepreneurs.

Similarly, it is not a question of whether world methanol prices will seek a new average price below the historical price as a result of increased plant size and improved technology, but only when. Our studies of the technologies and their economics suggest that the new level will be about \$110 ± 20 per ton, well below the historical \$133 ± 20 per ton level, and as low as \$80-100 per ton under long-term contracts.

The two most promising future fuel markets for methanol, and in each case this will be because of methanol's superior properties over other fuels, are fuel cell vehicles and domestic (household) fuel. The development of one will help the other because efficient distribution will be a common need for both.

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