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MODEL OF A STRATEGY FOR THE EUROPEAN ENERGY SUPPLY BASED ON METHANE AS THE PRIME ENERGY CARRIER

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Introduction

In this paper we examine, in the spirit of a Technology Assessement study, second order consequences of the introduction of Substitute Natural Gas (SNG) processes[1], using oil as feed-stock, whose development started in Great Britain about 20 years ago and has now reached its industrial maturity.

These SNG plants are a kind of reforming refineries where oil fractions and even crude oil are in a sense "burned" in steam according to the overall reaction:

$$4n\,[-CH_2-] + 2n\,H_2O \longrightarrow 3n\,CH_4 + nCO_2$$

The symbol $[-CH_2-]$ is meant to represent the building block of an aliphatic molecule, that without meaning that only aliphatic molecules can be used. The reaction is slightly exothermic.
Alternative processes[2] are based on straight hydrogenation, hydrogen being produced in the usual way by steam reforming part of the feed.

A very important feature of these SNG plants is that their investment and operating costs, and their efficiency is comparable to that of a current refinery producing the usual mix of oil products if we include desulfurisation.

The energy picture in Europe

Only 20 years ago there was no question of problems about procurement of energy in Europe. The existing recoverable coal reserves were sufficient for at least 200 years and only a small fraction of the energy needs was imported as oil from the very abundant reserves existing in the Middle East.
But aging of the coal mining industry, the intrinsic advantages of fluid fuels, and the "cheap oil "policy of the oil companies brought a profound change in the meantime.

In fact the present picture of the European energy supply, and the most authoritative forecasts show a high role of petroleum as the main source of energy (table 1)(3).
More than 95% of this petroleum is now imported: the dependence of the European Community on a highly unstable and politically conditioned market, so heavy today, will still grow in the future.
For structural and economic reasons coal consumption is not expected to increase in the future and nuclear energy, if restricted to the production of electricity, will not be able to cover more than a small fraction of the energy market in the near term (about 4% of the energy delivered to the consumer is forecasted to come by 1985 from nuclear plants).

Fairly recently natural gas has entered the picture. For its intrinsic merits it tends to substitute oil in fixed installations, the degree of substitution depending essentially from its availability.
The elasticity of a system in accepting natural gas is shown in fig. 1 giving the increase in gas consumption in the Netherlands following the discovery of the Groningen gas fields. It shows that, gas being

available, one can arrive easily to supply essentially all fixed installations.

Oil and gas reserves in Europe are given in table 2.[4] Although Europe cannot clearly rely only on these sources for its energy supply, we observe that proved gas reserves are equivalent to about five years total oil consumption at the present rate.

Natural gas as a fuel

That natural gas is a premium fuel for fixed installations is shown by the rapid and vast acceptance by the consumer whenever available. Availability in fact seems to constitute the only limit to a widespread use.
The advantages of methane as a fuel are the following:

1) It is the least pollutant of hydrocarbons, because it does not contain sulphur and because it burns cleanly (table 3).[5]

2) It needs simple burners, and the furnaces can operate unattended for long periods.

3) The distribution is made through underground piping: it is static and unobtrusive.
   The oil distribution system, based essentially on trucks, greatly contributes instead to the congestion of surface traffic.

4) The distribution costs for large quantities tend to give an advantage to methane.

5) No stocks are needed at the consumer site.

Methane may be used as a fuel for vehicles. In Italy about 50.000 cars run on methane, essentially for fiscal reasons, carrying it in heavy steel bottles. The use of fiber wound plastic containers may greatly improve the situation.
Bus and trucks using LNG are experimented in Italy, Switzerland and Germany.[6] The progress in low temperature insulation makes the losses due to boil off quite negligible (e.g. 1% per day).

However the point we want to make is that a perfectly usable, if not perfect, technology exists to run cars with Natural Gas. It may become compulsory to use Natural Gas in town as an antipollution measure as it has been proposed for the Los Angeles area.

The SNG Plants

Plants to produce SNG starting from an oil feedstock, (mainly naphtha fractions) were originally developed by the British Gas Council[1] and are now licenced around the world. Fig. 2[7] gives the simplified flowsheet for a SNG plant using a naphtha feedstock. We observe that a desulfurisation step is part of the process.
Following the evolution of the market the British Gas Council did extend its SNG processes to use all class of oil fractions as feedstock, including straight crude oil.

Table 4[8] gives an economic comparison of these plants in relation to the feedstock used. It will be observed that the economy of using cheaper feedstocks tends to be balanced by more expensive plants and lower transformation efficiency.
We must make two comments to this table, one that it is too schematic in the sense that allowing e.g. 10% of

the heaviest part of the crude to be used for other purposes like firing a power station, the efficiency and economics would be greatly improved, the other that the processes who handle crude are latecomers in the process of technological maturation.

It is important to observe that :

1) The investment cost for an oil-SNG plant and for a refinery of similar capacity are in the same bracket.

2) The efficiency, defined as the ratio between the heat value of the products and that of the feed are very near for an oil-SNG plant and for a refinery.

3) SNG comes out sulphur free. This is facilitated by the complete breakdown of the feed molecule.

Efficiency and investement costs appear at present less advantageous for the heavy fractions with a substantial discontinuity for a B.P. of 360°C. See fig. 5 ref.(8). Above this value capital costs increase by a factor of almost three, and energy losses almost double. In the authors opinion this is essentially due to the primitive state of SNG technology for this grade of feedstock, and this explain their tendency to use data referring more pertinently to naphtha reforming.

Distribution costs of Natural Gas vs Oil products

It is somehow difficult to assess the distribution costs of gas and oil in a really comparable basis due to the inevitable scatter of these process, the variable "mix" of oil products, and geography.
The ideal situation for our purposes is to compare the distribution costs from a refinery serving a certain area, assuming that :

a) the refinery produces the usual mix of oil products

b) the refinery produces only SNG

These distribution costs have been estimed, with the aid of oil and gas companies[9], for a typical european situation and reported in Table 5. These costs are clearly of the same order with an advantage for natural gas when consumption is increasing because the fine distribution nets are designed with an important overcapacity.

SNG as the main fuel

The previous data led us to consider the possibility of using SNG in the place of oil products, gradually substituting refineries with SNG plants and gradually extending the gas transport and distribution net.
Our analysis is a first order approximation aiming at evaluating the investment costs and the relaxation time of the system.

Taking as a reference the data from table 1, the increase of refinery capacity for the next ten years in Europe is expected to be 5% per year. Renewal time for equipment, excluding infrastructures and general facilities has been estimated conservatively to be about 10 years.
With these hypothesis, by inserting SNG plant in the natural turnover of refineries, an important fraction of the energy supply can be provided in form of SNG after few years (table 6).

Assuming that the sites of the SNG plants will be the same as those of the existing refineries, an hypothesis certainly non optimal, the length of the large bore pipeline network during these years will increase by about 2000 km/year. Compared with the already fast increase of the gas distribution net during the last years in Europe (Fig. 3) it is not expected that the capacity of fabrication and laying of pipelines becomes overstretched.
This means that in the limit of our approximation the gradual substitution of oil - oil products

distribution system with an oil - SNG distribution system can be done at essentially zero differential cost.

We have not included here the cost of the transformations at the consumer's end, e.g. for burners, because from the previous experience with natural gas we suppose the consumer has many marginal advantages which compensate for the expense of the substitution, e.g. simpler equipment, preheating of the fuel not necessary, storage tanks and stocks not necessary, automatic delivery.

An energy supply strategy based on natural gas and SNG

The fact that 95% of all oil consumption is at present imported, implies that the European Community depends very strongly on the Middle East. This dependency will increase in the future since the demand of oil is ever increasing. The threat of a sudden interruption is a real possibility and such an eventuality could be very dangerous to the Community. Moreover, the threat until it is not carried out may be used for several purposes and many times, e.g. for increasing the oil price. How the system works is shown by the recent increases of the crude oil prices.

It is true that Europe has now compulsory oil stocks for about two-three months. These stocks have a tactical importance as they can take care e.g. of a strike of the oil carriers, or similar short term occurences. It is however easy to demonstrate that they have no strategic importance, because they are paid in advance and therefore no damage can be done to the exporting countries by using them. (In fact these countries will benefit from large oil stocks by properly investing the corresponding money and because no measure of real importance, except war perhaps, can be taken in such a short lapse of time).

In our opinion a really important element of strength in bargaining with the exporting countries would be instead the ability for Europe to withdraw from the oil market for a substantial length of time, e.g. 5 to 10 years.

To get this capacity we propose a strategy based on the following measures:

a) Compulsory construction of SNG refineries instead of the current refineries to meet new capacity and to replace obsolete ones.

b) Use European gas fields as strategic reserves. The rate of depletion should rapidly go to zero and proper compensation measures be taken for the owners.

c) Construct an emergency trunkline system linking these gas fields to the gas transport network, with sufficient capacity to take care of the shutdown of all the SNG refineries.
About the possible rates of extraction from the gas fields, very high rate can be reached by gradually filling depleted gas fields and artificial reserves, e.g. "bubbles" in the water table.

<u>The cost of the strategy</u>

Referring to point a): as we have seen in the preceeding discussion the differential cost for manufacturing and distribution can be considered zero for the SNG produced to substitute oil products. So no cost should be charged to the strategy.

Referring to point b): if the gas reserves are "frozen" as strategic reserves a scheme has to be devised to compensate the owners of the fields and to keep research active. A very straightforward, if not subtle, form of compensation is that the Community buys the gas at the rate it <u>would</u> be extracted, e.g. 3% per year of the proven recoverable reserves. We estimate this compensation running at about $2{,}10^9$/year. This money is not really lost but in a sense frozen as it will be recuperated when this gas will be finally used.

Referring to point c): a possible emergency system is indicated in fig. 4 and the cost is evaluated at around \$ $8\ 10^9$ (table 7). <u>The system is not optimized.</u>

Table 8 shows the total net cost of the strategy assuming it has to be operative for 20 years, under the set of conditions described in the table. As a rule of thumb this cost referred to the oil consumption is equivalent to an increase in the oil cost of about $ 0.3/bll. It is certainly a not negligible amount but it should be compared with the recent increases of the oil prices, amounting to more than $ 1/bll. In other words if the only result of the strategy was to avoid a single increase in oil price of $ 0.3/bll., its costs would be completely paid.

Possible Improvements on the Basic Strategy

The boundary conditions we used being the most conservative, one can imagine improved versions of the strategy. E.g. the Norvegian gas, the Russian gas, LNG imports, coal fluidification and gasification, not to speak of new gas discoveries in Europe and of real optimization on the layout and the operation of the gas grid, are all strategic assets in the sense they can reduce the costs for implementing the strategy and increase the length of time the Community is able to withdraw from the market.

- The importance of Norvegian and Russian gas are obvious, and some details are given in fig. 5.
- LNG imports make SNG plants unnecessary for the relative share of the market, although specific investments are not very different for the two chains. However a LNG tanker fleet can be precious if the strategy should include all oil importing countries (OPIC).
- If coal fluidification could mobilize, at competitive prices, even part of the 100 billion tons of coal present in the Community, its importance is also obvious.

- About the gas grid, the relative location of gas fields and SNG plants is obviously a sensitive parameter in the total cost of the grid. A non obvious point is that, thanks to the emergency trunklines, the gas fields can be used as back up or as daily and seasonal "lungs" for the SNG plants who can operate always at full capacity and without reserves. The resulting economies in capital and operating costs should be written off the costs of the emergency grid.
- Dividing Europe in blocks of consumption and natural gas reserves, we find a fairly good match between them except for the southern block, so this block requires very long and large emergency lines coming down from the north. The size of these lines could be strongly reduced if they were used to beef up the local emergency reserves by slowly replenishing more or less depleted local gas fields, or even reservoirs artificially created, e.g. in acquifers. This will also facilitate high rates of gas supply to the emergency network.

Conclusions

Our analysis, although based on first order approximation shows clearly that SNG technology can bring in the advantages of Natural Gas: low pollution, unobtrusive distribution, and simplicity in use; with marginal cost differentials by respect to the present system.

- It shows also that the SNG system can rapidly penetrate the energy market by taking advantage of the rapid turnover of refinery equipment and of the expansion of the market itself.

- As a kind of fall out, the technical possibility of acquiring a much needed bargaining strength toward the oil exporting countries, is indicated and its cost evaluated. In the authors opinion the implementation of such a strategy would take much steam off the hysteria from impotence, that now characterize the attitudes of the oil importing countries. And the oil exporting countries would certainly benefit, in the long term, if the counterpart, so strong in so many ways, feels reasonably secure.
  Still in the authors opinion however, the necessary degree of political coordination necessary for the actual implementation of the strategy is a pious dream.

TABLE 1

Primary Energy Consumption in the Community : Units M Tce

	Solid fuel		Liquid fuel		Natural Gas		Prim. Electricity *		Total
1960	476	(64%)	214	(29%)	13	(2%)	39	(5%)	742
1965	453	(48%)	423	(45%)	22	(2%)	40	(4%)	938
1970	368	(31%)	653	(56%)	88	(7.5%)	55	(4.7%)	1164
1975	292	(19.6%)	905	(61%)	203	(13.6%)	88	(6%)	1488
1980	267	(14%)	1165	(62%)	296	(16%)	163	(8.6%)	1891
1985	246	(10%)	1459	(61%)	381	(16%)	292	(12.5%)	2378

* Primary electricity is expressed in the equivalent tons of coal which would be necessary for producing this electric energy by classical thermal power plants

TABLE 2

Natural Gas Reserves and Oil Reserves of in the European Community for the Year 1972

	Gas (10^9 m^3)			Oil (10^6 t)
	Confirmed	Estimated	Total	Confirmed
Netherlands	1990	342	2332	37.3
Gr. Britain	700	300	1000	686.9
W. Germany	202	72	274	81.6
Italy	180		180	32.9
France	215	85	300	12.8
Denmark		50	50	33.3
	3237	849	4136 (=4550 Mtce)	885 (=1248 Mtce)

TABLE 3

Pollutants from oil and gas-fired equipment

(Kg of pollutant per ton of fuel)

	Fuel oil	Natural gas
Sulphur oxides (as SO_2)	30	/
Nitrogen oxides (as NO_2)	13.5	6.9
Organic acids (as CH_3COOH)	13.5	1.3
Aldehydes (as HCHO)	1.3	1.0
Other organics	4.6	1.4

TABLE 4

SNG Production Cost Factors for Various Feedstocks, mills/Nm^3 - Gas Capacity 7.10^6 Nm^3/day

Feedstock	Naphtha	Kerosine/ Lt. Gas Oil	Med/Heavy Gas Oil	Crude
Utilities, Catalyst, etc.	1	1.1	1.3	1.5
Labor and Related Overhead	0.4	0.4	0.6	1.0
Capital Charges	4.4	7.4	10.8	13.3
Total Non-Feedstock Cost	5.8	8.9	12.7	15.8
Thermal Efficiency, %	91	90	84	79
Investment 10^6 $	70	70	105	130

TABLE 5

Natural gas transport and distribution cost for a typical situation

Transport cost (from the harbour to the city gates)

	Natural gas (by pipeline)	Oil	
		(by pipeline)	(by tank car)
For an average distance of 300 Km($/Tcal)	380	200	600

Distribution cost (from the city gates)

Use	Natural gas ($/Tcal)	Heating Oil	
		($/Tcal)	$/t
Residential	2100	1500	15
Commercial	1350	1500	15
Industrial	200	120 - 500	1.2 - 5

TABLE 6

The energy consumption in Europe in 1982 under three different circumstances. Units are 10^6 tce.

CASE I		CASE II		CASE III	
Solid fuel	258	Solid fuel	258	Solid fuel	258
Oil	1275	Oil	271	Oil(Nord Sea)	200
		SNG from oil	1004		
Nat. Gas	327	Nat. Gas	327	Nat. Gas	1040
Prim. El.	206	Prim. El.	206	Prim. El.	206
	2066		2066		1704

Case I - Under normal conditions. Derived from table 1

Case II - If oil-refineries are started to be replaced by SNG refineries in 1975 according to the hypotheses described in the text.

Case III - As in Case II, but the oil imports are interrupted starting from 1st Jan. 1982 and the energy consumption reduced by 20%. The Nord-sea oil from the territory of the Community will completely be used for transport.

TABLE 7

Additional trunk lines network needed in emergency conditions (end 1980)

	Pipeline Length (100 Km)	Additional capacity (Gcal/sec)	Cost of the additional line (10^9 $)
Groningen-Amsterdam	1.8	158	2.1
Amsterdam-Rotterdam	0.68	120	0.58
Rotterdam-Köln	2.40	36	0.62
Köln-Frankfurt	1.83	25	0.32
Frankfurt-Karlsruhe	1.52	18	0.21
Karlsruhe-Stuttgart	0.76	19	0.10
Stuttgart-München	2.20	18	0.30
Rotterdam-Antwerpen	0.87	54	0.34
Antwerpen-Charleroi	1.08	24	0.18
Charleroi-Lille	1	32	0.23
Lille-Paris	3	18	0.37
North Sea-London	2.9	25	0.51
North Sea-Liverpool	3.6	37	0.96
North Sea-Danemark	3	7	0.15
Cortemaggiore-Firenze	1.5	6	0.56
Firenze-Napoli	4.8	6	0.19
		Total	7.71

The investment cost for the pipelines, for their installation and for the pumping stations has been calculated following the optimization procedure indicate in ref. 10 . However no effect of scale has been taken into account for heat flows higher than 10 Gcal/sec (corresponding to a maximum pipe diameter of about 1.7 meters).

TABLE 8

Cost of the strategy for a 20 years period

Cost of the strategy (10^9 \$)			Cost of the equivalent oil stock (10^9 \$) (3)			
Total discounted cost (1)	Annual cost (2)		Stock equivalent to the gas reserves (4)		Stock equivalent to 1 year consumption (1980) (5)	
Freezing the reserves: 11.4 Emergency trunk lines: 14.3	Constant rate	Rate proportional to the consumption. Rate at the year 1980	Discounted	Annual	Capital	Interests (8%)
Total 25.7	2.75	1.93	53.5	5.7	16.3	1.3

1. The total cost of the strategy is calculated as the sum of:
   - the economic penalty due to the deferred use of 3%/year of the European gas reserves
   - the cost of an emergency trunk-line network designed for the European needs in 1980 and expanded at the rate of 5%/year to take into account the annual increase in consumptions. These costs are discounted to the first year in which the strategy is operating (1980) with a discount rate of 10%. The value of the gas is calculated as the equivalent to a cost of 20\$/ton for the oil following the procedure suggested in ref. 11.
2. The total costs are translated into a constant annual rate or in an annual rate proportional to the oil consumption (assumed to increase by 5%/year).
3. As a comparison, the cost of an oil stock has been calculated in two cases. Only the cost of oil (at 0\$/ton) to be put in stock has been included and not the cost of the storage tanks; the latter will be about of the same amount as the former, therefore doubling the total cost.
4. A total discounted cost and a constant annual cost are calculated for an oil stock which has the same energy content as the european gas reserves.
5. The capital cost and the interest to be paid on it are calculated for an oil stock equivalent to the annual consumption in 1980.