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THE USE OF NATURAL GAS IN ELECTRICITY GENERATION IN THE ARAB COUNTRIES*

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* Issued without formal editing.

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Table of Contents

LIST OF FIGURES

LIST OF TABLES

LIST OF ANNEXES

EXECUTIVE SUMMARY

Natural gas reserves are found in thirteen Arab countries . Proven gas reserves in these countries amounted to about 23 trillion cubic meters or 21% of the total world reserves. The use of natural gas has grown very rapidly in all Arab gas producing countries. The percentage of gas flared in the Arab countries dropped from 70% in 1971 to about 9% in 1990 . The volume of gas used in commercial applications has grown at an average annual rate of 7% from 70 billion cubic meters in 1980 to about 140 billion cubic meters in 1990 .

Natural gas is the cleanest of all fossil fuels, and is seen as part of the solution to environmental pollution.

Technological advances in the field of combined heat and power production have given rise to much more efficient and economic means of generating electricity from gas. Many electric utilities in the Arab countries are experiencing financial difficulties , but are still faced with high capital requirements for system expansion to maintain electricity supply . Arab countries with natural gas reserves have an opportunity to produce low - cost electricity using gas - fueled large - scale combined - cycle power plants . The advantages of gas - fueled combined - cycle systems are

- Higher thermal efficiency : 50% compared to 38% for oil or coal - fired conventional power plants .

- Capital costs are much lower : about US$600/KW installed compared to more than US$1000/ KW installed for competing power plants .

- Cooling water requirements are lower .

- Construction time is about 2 years compared to about 3-5 years for other fossil - fuel power plants .

- Start up and loading times are shorter than traditional plants .

- Lower operating pressures on the steam side of the combined - cycle plants compared to conventional steam plants .

- Mainteance costs are lower than conventional steam plants.

- Better environmental impacts .

Economic analysis clearly indicates that gas-fueled combined -cycle power plants are the least-cost alternative for both large and small systems. Ongoing development work on gas turbine technology indicates that gas - fueled combined - cycle power plants are likely to assume major new roles in power generation over the next 30 years .

There is good potential for all Arab gas producing countries to convert power plants from oil to gas and save oil for export . Power requirements will be provided , in the future, by gas-fueled combined -cycle plants because of their cost - effectiveness and positive impact on the environment . The linkage of five regional power grids among the Arab states can lead to the eventual consolidation of a pan- Arab electrical system . This system will provide an efficient and reliable source of low - cost electricity . A large percentage of this power could come from natural gas which would otherwise have no market .

Eventual connection of the pan - Arab grid with Europe is the ultimate development that brings Arab gas into the most optimal relationship with the global energy market .

1 - INTRODUCTION

Gas development is only possible when production from discovered reserves finds market outlets and stands a chance of displacing competing fuels or of securing a share of incremental demand for energy .

Natural gas reserves are found in thirteen Arab countries . However, unlike oil which is easy to produce, to use and is widely traded internationally , only 8% of natural gas produced in the Arab countries is marketed beyond national boundaries and less than 60% of that production is used in the local markets .

This paper examines the economics of natural gas utilization as fuel for electricity generation compared to other fossil fuels . The prospects of exporting gas in the form of electricity through high voltage electrical lines instead of exporting it through gas pipelines is also reviewed . A model for the optimal development of gas is provided in the concluding section.

2 - ARAB GAS RESERVES

Proven natural gas reserves of the Arab countries amounted to about 23 trillion cubic meters or 21% of the total world reserves in 1991 (see annex 1) . These reserves are distributed among 13 countries as shown in Table (1) . Some of these countries are relatively richly endowed with gas, namely , Algeria , Iraq , Libya, Saudi Arabia, Qatar, Kuwait and United Arab Emirates. Modest reserves are found in Bahrain , Oman , Egypt , Syria, Tunisia and Yemen . Although these reserves are small compared to those of the first group, they are often large in relation to the potential of the local markets.

The use of natural gas has grown very rapidly in all Arab gas producing countries over the last two decades. The percentage of gas flared in the Arab countries dropped from about 70% in 1971 to about 9% in 1990 (annex 2) . The volume of gas re-injected rose by 11% per annum during the period 1980 -1990 from 27 billion cubic meters in 1980 to about 75 billion cubic meters in 1990. The volume of gas used in commercial applications rose from 70 billion cubic meters in 1980 to about 140 billion cubic meters in 1990, an in crease of 7 percent per annum .

Table (1)

Arab Gas Reserves
1991

Country	Gas Reserves Billion Cubic Meters
UAE	005100
Saudi Arabia	004700
Qatar	004100
Algeria	003000
Iraq	002400
Kuwait	001250
Libya	001099
Yemen	000179
Syria	000179
Egypt	000307
Oman	000258
Bahrain	000153
Tunisia	000077
Sudan	000077
Total	022966
Total World	111969
Arab reserves /World%	000021

Prospects are good for discoveries of additional reserves . In fact , it is likely that in future more gas than oil will be discovered in most of the Arab oil and gas producing countries .

3 - GAS CLASSIFICATION

An important distinction must be drawn at the outset between associated gas, free gas , and natural gas liquids. The development of associated gas, (whereby natural gas is found associated in the same formation with oil and is thus produced simultaneously with oil) is different from the development of free gas where the economics of the oil/gas field clearly justify the priority for oil . A further distinction between associated gas and free gas development is that associated gas production , by its nature , is not as predictable as free gas . This is because the underlying crude oil production determines the daily natural gas volumes produced. Temporary reductions in crude output mean concurrent reduction in natural gas produced .

If the natural gas is found in a discovery contains a high proportion of liquid condensates , this gas is economically closer to crude oil than to dry gas. Gas condensates have a world market and are easier and less costly to transport than dry gas .

4 - GAS AND COMPETING FUELS FOR ELECTRICITY GENERATION

Since gas is only one among many sources which can be utilized for generation of electrical energy, it is very important to look at its advantages and disadvantages with respect to the alternatives . This is essential in order to justify the capital expenditure required for field development and related infrastructure .

Natural gas is the cleanest of all fossil fuels , and is seen as part of the solution to environmental pollution.

Technological advances in the field of combined heat and power (CHP) production and combined -cycle power plants have given rise to much more efficient and economic [5 means of generating electricity from gas (annex 3) . However, oil and gas are still in a broad sense , major substitutes. To think of them in exactly the same terms is misleading and may have caused some of the problems in the development of gas as a fuel . The first difference lies in the availability of markets for oil and gas. Markets for oil exist in all countries of the world and it's uses are well-established . In contrast , a gas field cannot be developed unless there is an identified market and firm sales arrangements have been made . Because gas development involves dedicated markets and the construction of a transportation facility between the gas field and the final user, a gas project must be conceived as an interrelated package including up-stream investment, transportation , and the promotion of markets down stream.

The second major difference between oil and gas is transport . Due to the fact that oil is consumed as products rather than crude, a wide range of transport facilities are used for distribution , including pipelines, trucks, tankers, barges...etc . In contrast , gas is taken from the field to its final point of use by pipeline which makes it uneconomical for small quantities. In addition, gas pipelines are more expensive than oil pipelines per ton of oil equivalent . The relation between producers and buyers is very different for oil and gas . The producer of oil can deal with many buyers while a gas producer typically deals with only one or at most , a few . Furthermore , the relationship between gas producers and buyers is inherently a long- term one , because of the infrastructure involved. This leads to a very different economic relationship and a very different market structure .

To summarize , gas development is critically dependent on the existence of a large market with a reliable demand . The power sector is the major candidate in most of the Arab gas producing countries which fortunately have a large and rapidly growing demand for electrical energy (annex 4) .There is great potential for using gas in new power stations . In addition there is considerable room for conversion of existing capacity. In some cases it is more economic to build a power station close to a gas field and transport the electricity rather than the gas, because of terrain or other factors. The case for using gas in electricity generation rests on a number of factors . These include: environmental issues and the economic efficiency gains from low-cost combined -cycle power systems . Even gas-fired steam turbines are more efficient and less expensive to operate and maintain compared to fuel - oil or coal-fired steam turbines. Gas should be used more widely in the power sector than at present . The most common application scenario would involve the linkage of a power station (s) with a gas field by a pipeline , assuming economic benefits justify construction. Bringing gas to the power station (s) also serves the longer-term goal of gas distribution to industrial and residential users. This approach will prove to be the best model for the development of the energy sectors of the Arab gas producing countries .

5 - GAS FIRED COMBINED HEAT AND POWER (CHP) SYSTEMS

In broad terms , CHP systems can be classified in three categories according to engine size . Small - Scale CHP systems are sized up to 200 kW of electrical output . Medium- Scale CHP ranges from 200 kW up to 20 MW . Large- Scale power generation schemes are above this size .

5.1 Small - Scale CHP Systems

Small - Scale CHP typically uses a reciprocating gas engine driving an alternator which provides all or part of the base electrical load(see fig 1) . Heat from the engine exhaust and cooling systems is recovered and used principally for space and water heating . These engines are small and compact and can be easily integrated into existing heating systems . Usually they have an operation efficiency of over 75% .

Capital and installation costs of small- scale CHP systems are relatively low and are based on generally reliable automotive engines .

5.2 Medium - Scale - CHP Systems

Medium - Scale CHP are usually based on gas turbine technology (see figs 2+3) . Medium - Scale CHP is most likely to be found in industrial applications . There are many successful installations world- wide using gas turbines and waste heat boilers . An important feature of this type of system is the ability to inject gas directly into the exhaust gases heating the waste heat boiler to increase steam production and enhance flexibility . Exhaust gases from the turbine are clean and can be used directly for producing steam or hot water.

The capital cost of medium-Scale CHP systems is relatively low and those systems give a high return on capital with payback in less than five years. Improved design , performance and reliability mean that these systems offer high efficiency with lower outage rates .

5.3 Large - Scale Power Generation and Co-Generation

All Arab countries with natural gas reserves have the opportunity to produce low-cost electricity using gas - fueled large - scale power generation systems , known in the literature as combined -cycle power plants (see figs 4+5) . Combined - cycle units utilize one or more gas- turbine generators which vent exhaust gases into a waste heat boiler. This provides steam for single steam turbine generator,thus forming a combined - cycle block (see fig 6) . Combined- cycle blocks of 600 MW are now being marketed.

The advantages of gas-fueled combined -cycle systems can be summarized as follows .

a) Thermal efficiency is about 50% compared to 38% or less for oil or coal - fired conventional power plants.

b) Capital costs are much lower : about US$ 600 /kW compared to about US$ 1000 /kW installed for oil-fired , and US$ 1300/kW installed for coal-fired conventional steam plants.

c) Carbon dioxide emissions are less than 45% of those of coal-fired steam plants and less than 60% of those of oil-fired steam plants .

d) Cooling water requirements are lower.

e) Construction time is about 2 years compared to about 3-5 years for other fossil-fuel power plants .

f) Start up and loading times are shorter than traditional plants . Response time for gas turbines and lower operating pressures on the steam side of the combined - cycle are clear advantages over conventional steam plants.

g) maintenance costs are lower than conventional steam plants .

6 - ECONOMICS OF GAS-FUELED COMBINED - CYCLE POWER PLANTS

Economic comparison between gas-fueled combined -cycle power plants and competing alternatives of coal and oil thermal power plants easily supports combined - cycle systems . Analyses were made for both large systems of 2000 MW (installed capacity) and above as well as for small systems , below 500 MW .

The assumptions used in the analysis of generation costs shown in annex 5 . Fuel price assumptions were : US$ 1.8/MJ for natural gas,US$ 40/ton of hard coal , US$ 13/bbl for fuel oil and US$ 26/bbl for diesel oil . A plant factor of 65% was assumed for all alternatives . A conservative 47% thermal efficiency was assumed for combined-cycle units, even though efficiencies of more than 50% were obtained in several places.

Table (2) compares electrical plant generation costs for four types of thermal plants .

Table (2)

Thermal Plants Generation Costs

Plant Type	US¢/kWh
Large Systems	
Gas - Combined - Cycle	2.85
Coal - Steam	4.00
Fuel - Oil Steam	4.30
Distillate Combined - Cycle	4.60
Small Systems	
Gas Combined - Cycle	3.1
Coal - Steam	4.7
Fuel - Oil Steam	5.1
Low - speed Diesel-Engines	4.7
Distillate Combined cycle	5.3

The above table demonstrates that gas - fueled combined-cycle power plants are the least cost alternative for both large and small systems . Sensitivity tests have shown that gas-fueled combined - cycle is competitive for both large and small systems with gas prices up to US$ 2.75/MJ . Combined -cycle systems remain competitive even where capital costs are increased by 25% from US$ 600 /kW installed to US$ 750/kW installed (annex 6).

7 - ENVIRONMENTAL IMPACT

Fossil fuels account for more than 75% of current world energy consumption . This heavy utilization of fossil fuels is causing serious environmental impact in the form of carbon dioxide ,and nitrogen oxide.Acid smut is also produced because of the presence of sulphur in most of the fossil fuels available world-wide . Some 38% to 42% of the world's fossil fuel consumption is for power generation . The amount of pollutants emitted to the environment varies considerably according to the type of fossil fuel, type of power plant , and its thermal efficiency . Recent studies have shown that emissions from gas-fueled combined - cycle power plants are only 45% of those from conventional coal and about 60% of fuel - oil fired steam power plants . This is shown in table (3) .

Table (3)

Environmental Impacts of Different Types of Power Plants

Emissions Per kWh	Coal Steam With Scrubber	Fuel-oil Steam	Gas - Fueled Combined Cycle
CO_2 grams	900	720	380
CO mg	090	072	040
SO_2 mg	060	020	000
NO_2 mg	600	480	350

As the above table indicates , the production of green house gases can be reduced substantially by using gas-fueled combined - cycle plants instead of fuel-oil or coal-fired steam power plants .

8 - FUTURE POWER GENERATION TECHNOLOGIES

At present the most cost -effective fossil fuel power plant for base load operation is the natural gas-fueled combined-cycle power plant assuming gas is available. This is followed by coal -fired steam power plants. Where both oil and gas are available , the relatively high price of oil in the international markets and opportunities for export of oil rule out both fuel oil-fired steam units and distillate - fueled combined-cycle power plants. Ongoing development work on gas turbine technology indicates that gas -fueled combined-cycle power plants are likely to assume major new roles in power generation in both industrialized and developing countries over the next 30 years . In the future : new , highly efficient gas - fueled combined cycle power plants will be able to provide electricity at a lower cost and with less adverse environmental impacts and safety problems than fuel-oil fired, coal-fired or nuclear power plants .

9 - POTENTIAL FOR ARAB GAS PRODUCING COUNTRIES TO USE GAS FOR ELECTRICITY GENERATION

At present , natural gas is used for production of electrical energy in almost all Arab gas producing countries . Share of natural gas in total fuel used for power generation in these countries varies from less than 10% in Syria to more than 95% in Bahrain .

There is good potential for all Arab gas producing countries to convert power plants from oil to gas and save oil for export in order to gain optimal use of this natural and limited resource ,power requirements can be provided , in future , by gas - fueled combined- cycle plants because of their cost-effectiveness and positive impact on the environment . At a later stage groups of Arab countries could be interconnected by a common electrical grid . These could take the following configuration :-

* The Northern - Eastern Group : This comprises the electric utilities of Iraq , Jordan , Lebanon , Syria and Egypt (fig 7)

* The Saudi Arabian Group : This integrates the four major electric utilities within the country (fig 8)

* The Yemen Group : This links the electric grids in the north and south of this country .

* The Gulf Group : This comprises the electric networks of Bahrain , Kuwait , Oman , Qatar , UAE and the eastern part of Saudi Arabia .

* The Maghreb Group : This brings together the electric utilities of Algeria , Tunisia , Libya , Morocco and Mauritania (fig 9) .

There is at least one major gas producing country in each group . This means that most of electricity generation in the Arab countries could eventually be produced from natural gas . At a final stage the electrical grids of the five groups could be interconnected into one system (fig 10) which will enhance the technical efficiency and economic performance of the electrical sector in these countries.

With the expected development in the field of electrical transmission lines technology , it is eventually possible that Arab electrical systems could be interconnected with Europe through Turkey in the North East and through Spain from the West (fig 11). This will enable Arab gas producing countries to export their gas in form of electrical energy , thereby enhancing the economic competitiveness and fully realizing the potential of this commodity .

10 - CONCLUSIONS

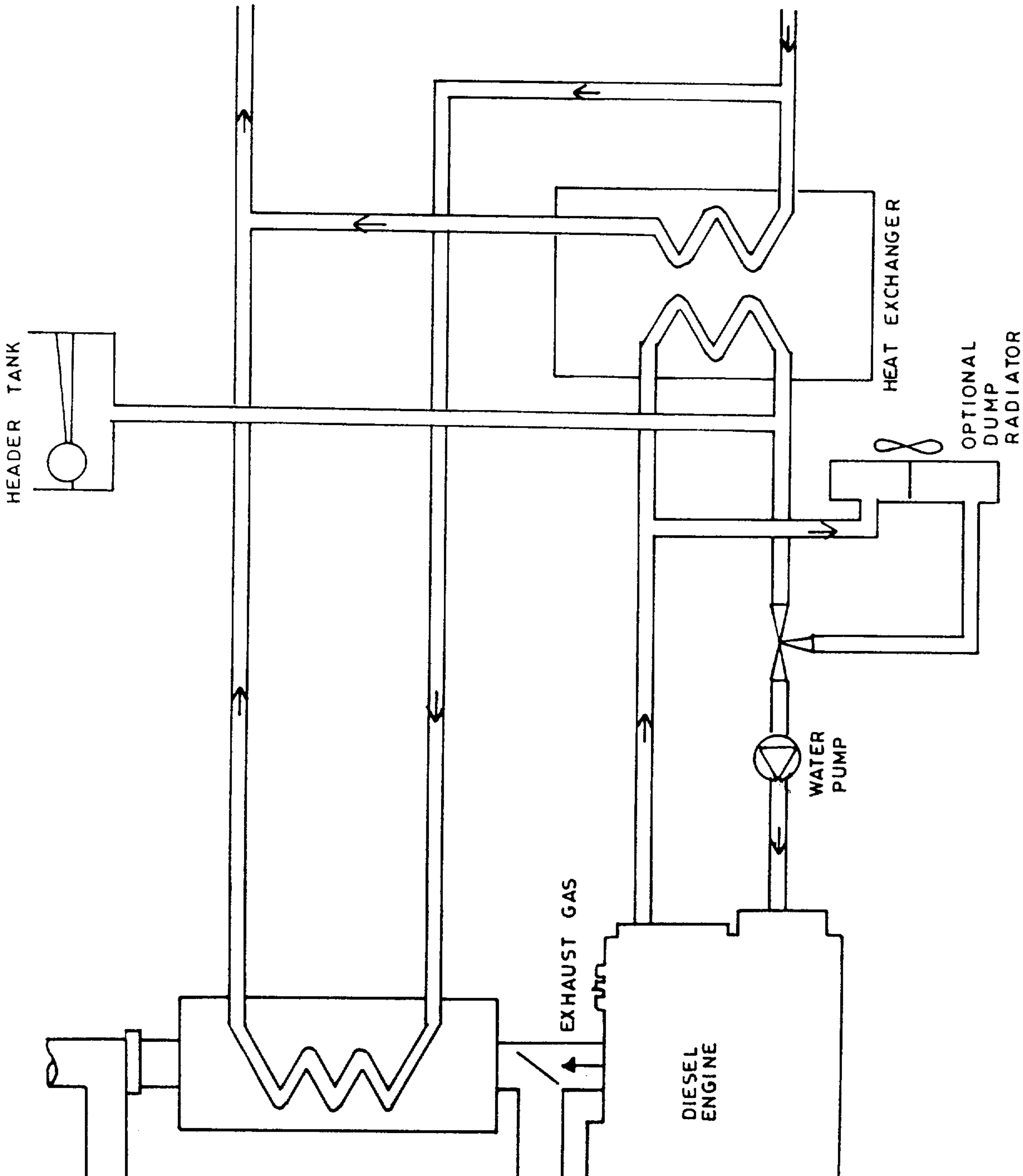
This paper has shown that natural gas is the most cost-effective option for electricity generation in many Arab countries . Natural gas is also the cleanest environmental alternative of all fossil fuels. Reserves of natural gas linked to high efficiency combined-cycle turbines will account for a rising and significant proportion of power generation in the Arab countries in the future .

The linkage of five regional power grids among the Arab states can lead to the eventual consolidation of a Pan-Arab electrical system . This system will provide an efficient and reliable source of low-cost electricity for economic growth . A large percentage of this power will come from natural gas which would otherwise have no market .

Eventual connection of the Pan-Arab grid with Europe (via Turkey and Spain) is the ultimate development that brings Arab gas into the most optimal relationship with the global energy market .

SMALL-SCALE CHP SYSTEM

FIG. (1)



MEDIUM- SCALE CHP SYSTFM

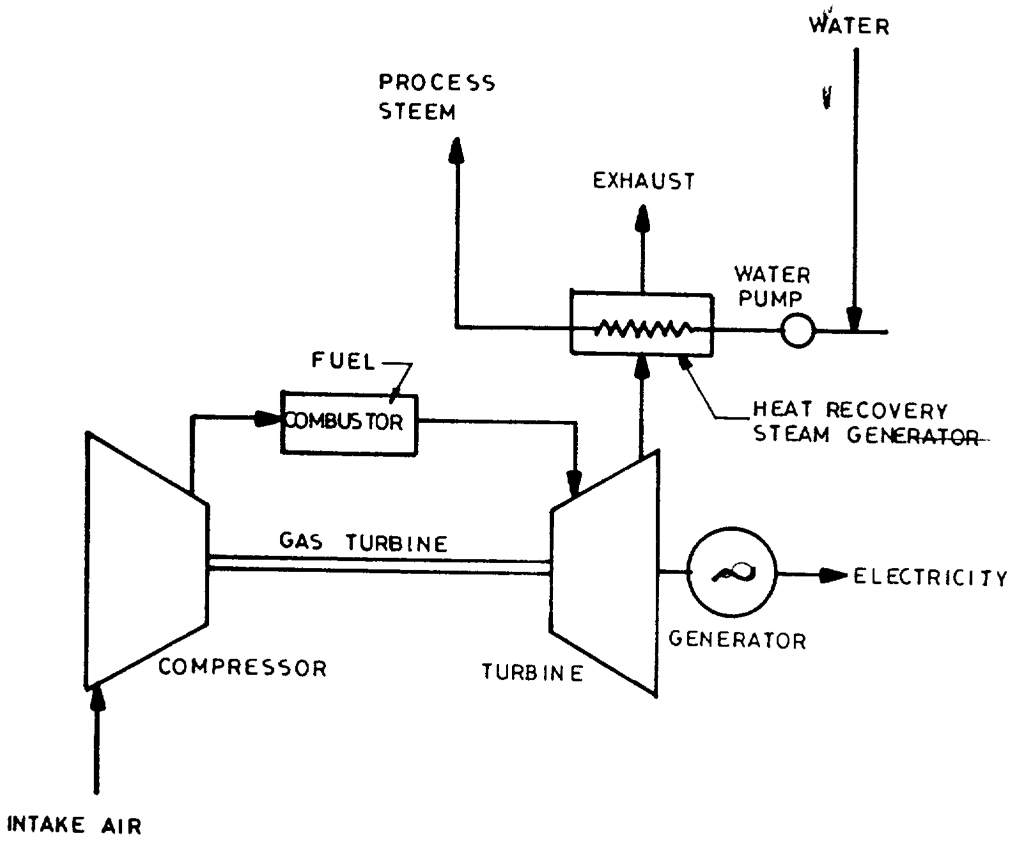
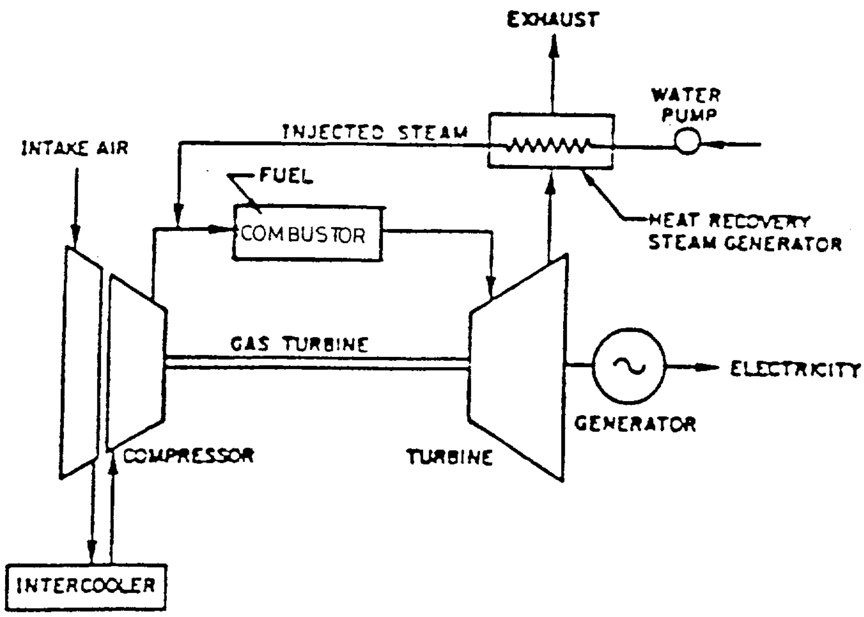


FIG. (2)

Steam-Injected Gas Turbine with Intercooler



(FIG. 3)

COMBINED - CYCLE UNIT

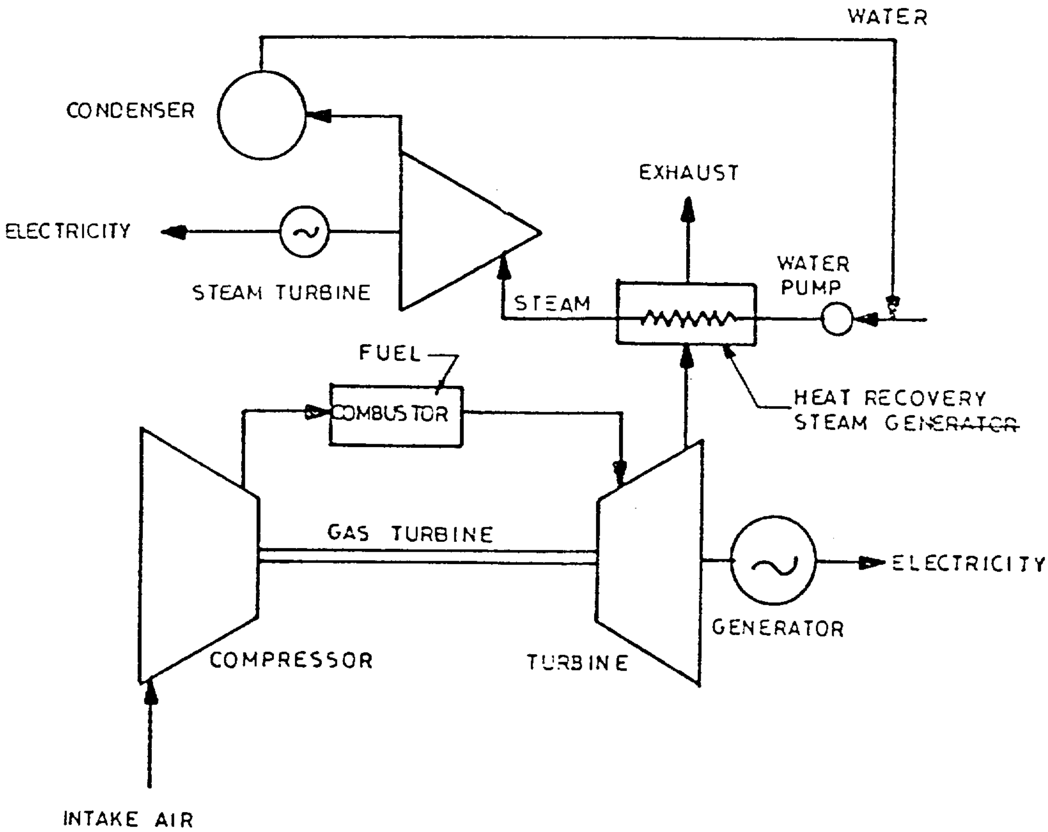


FIG. (4)

COMBINED-CYCLE COGENERATION UNIT

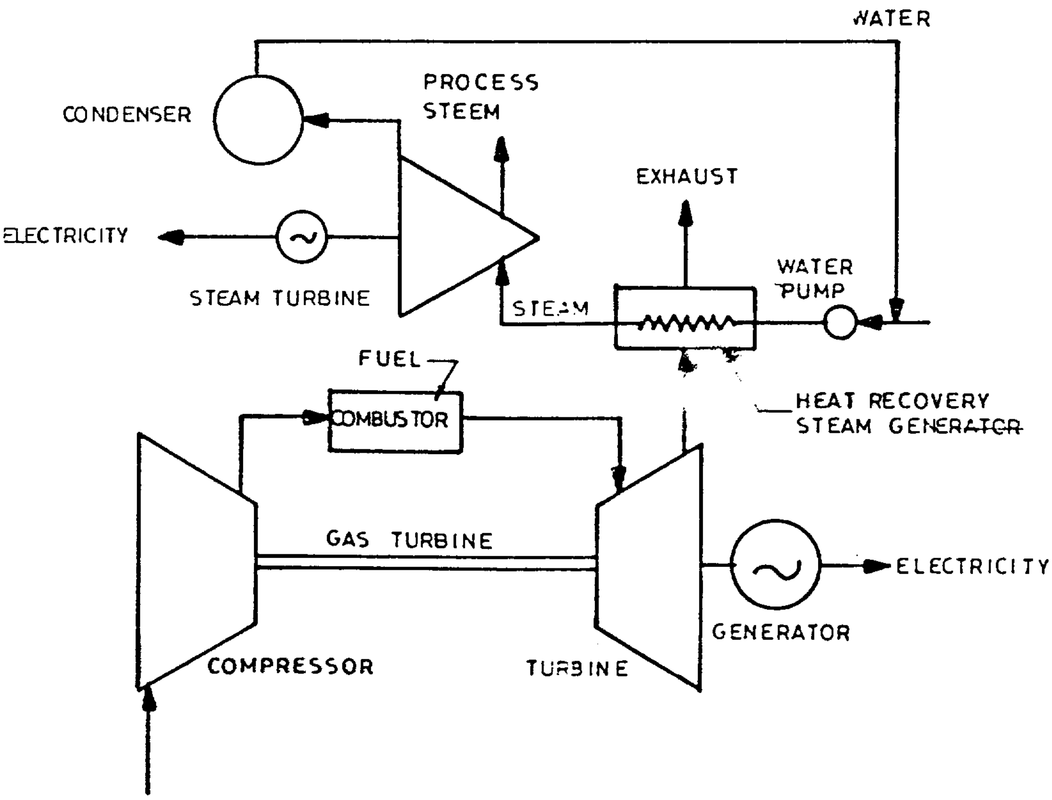
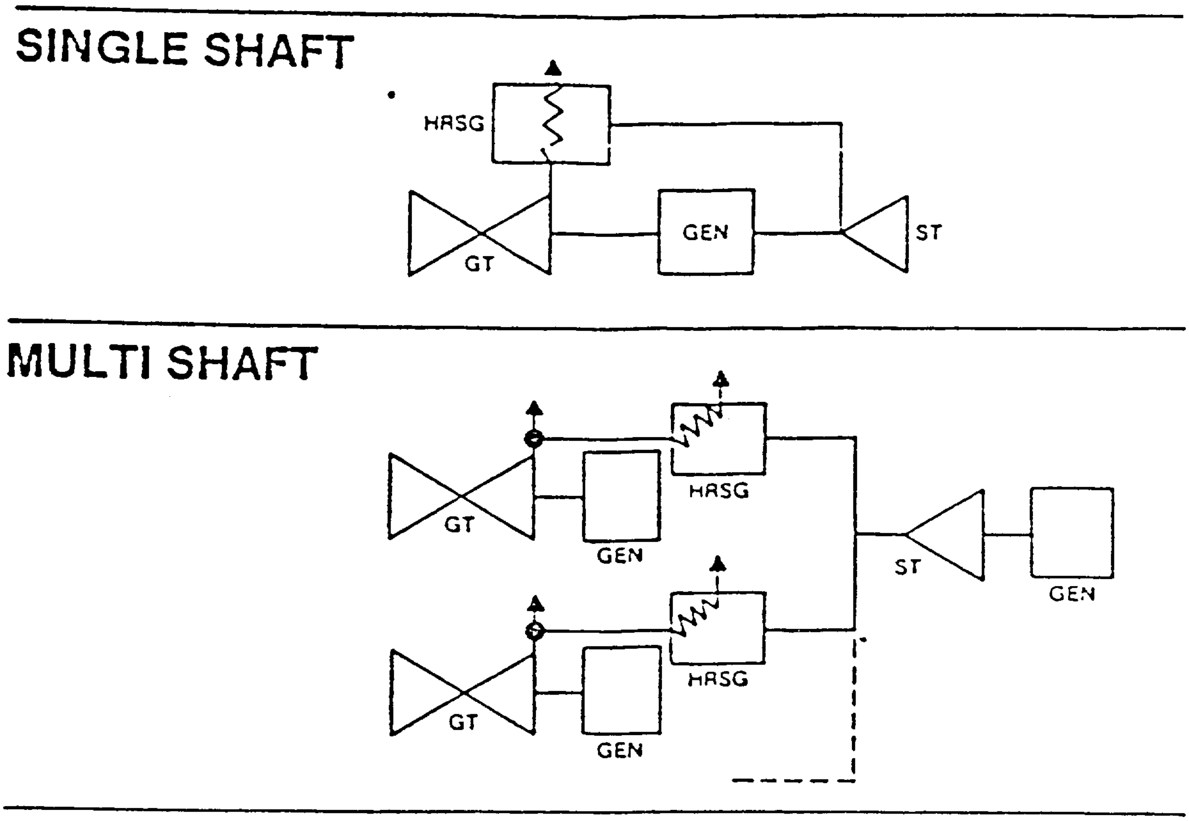


FIG. (5)

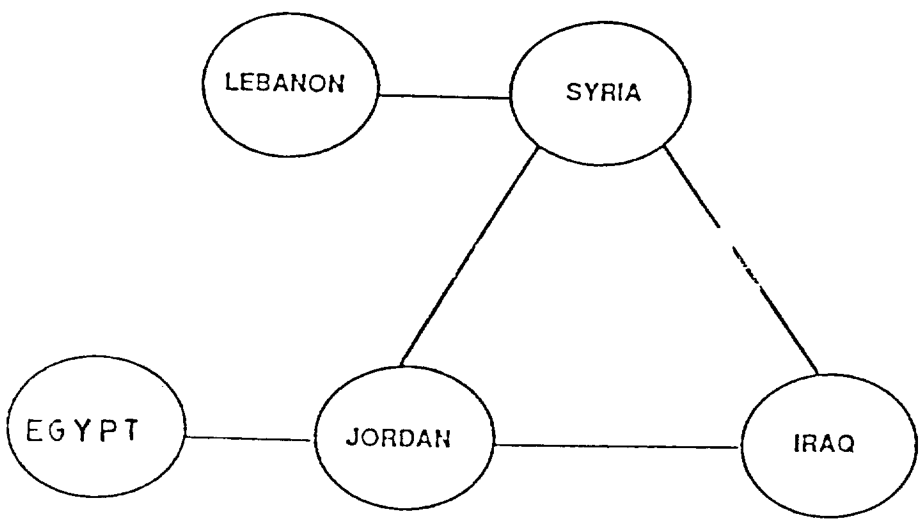
Combined-Cycle Shaft Arrangements



(FIG 6)

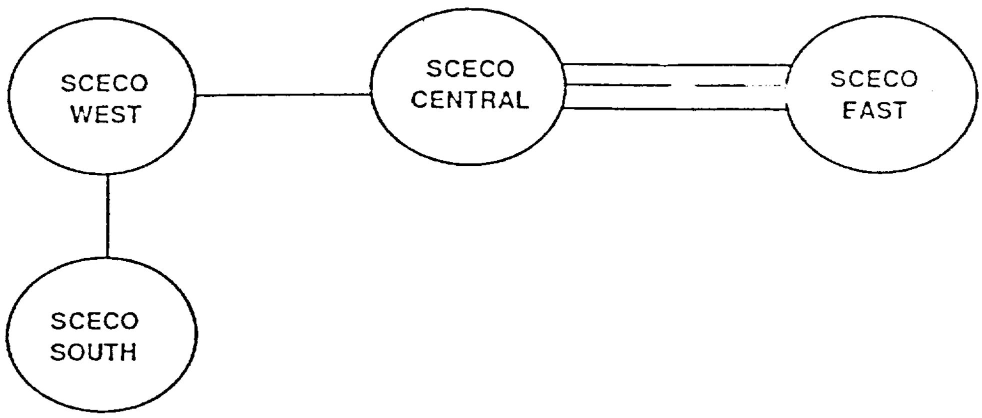
SOURCE : Willians & Larson " Aeroderivative turbines for stationary POWER , The Centre for Energy and Environmental studies , prinlleton University, May 1988 .

INTERCONNECTION CONFIGURATION PROPOSED FOR THE EASTERN- NORTHERN
CONNTRIES



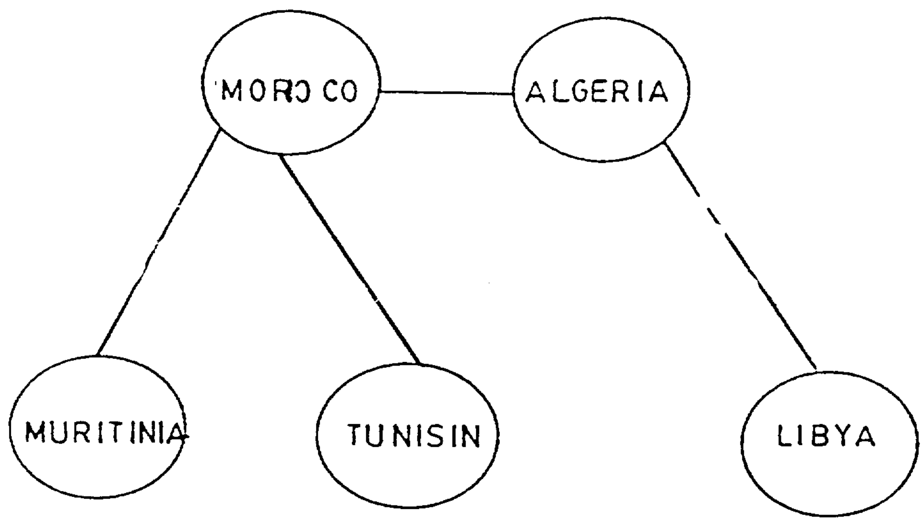
(FIG. 7)

Interconnection configuration proposed for Saudi Arabia.



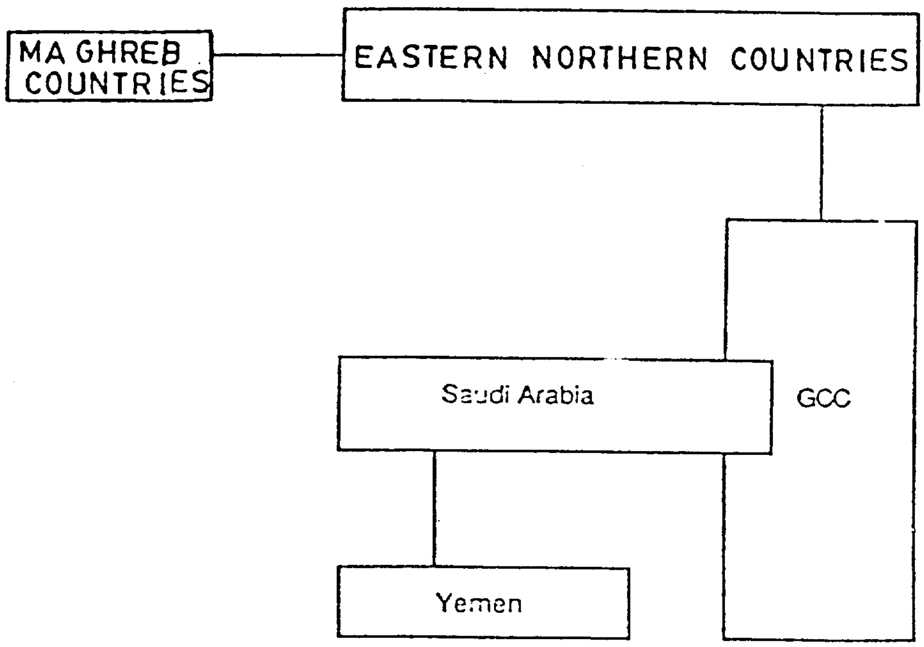
(FIG 8)

INTERCONNECTION PROPSED FOR MAGHREB COUNTRIES



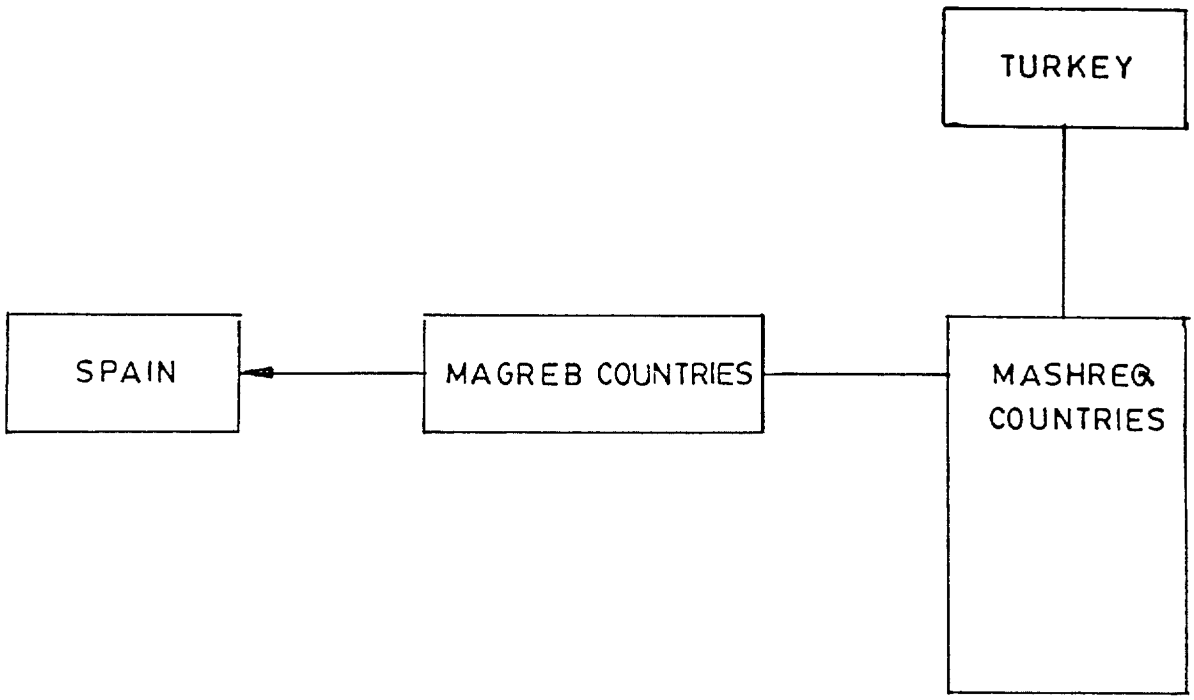
(FIG. 9)

PAN_ARAB ELECTRICAL GRID



(FIG.19)

EUROPE – ARAB INTERCONNECTION



(FIG. 11)

Annex (1)
World Proven Natural Gas Reserves 1991
Billion Cubic Meters

COUNTRY	BCM
ASIA PACIFIC	
Afganistan	90.28
Australia	385.09
Bangladesh	654.73
Brunei	286.45
China	905.37
Taiwan	17.14
India	659.13
Indonesia	1658.24
Japan	24.76
Malaysia	1510.36
Burma	239.13
New Zeland	88.21
Pakistan	578.01
Papua New Guinea	204.60
Phillippines	2.56
Tailand	347.83
Veitnam	2.56
Total Asia Pacific	7654.42
WESTERN EUROPE	
Austria	9.92
Denmark	103.81
France	33.15
Germany	224.04
Greece	1.13
Ireland	43.48
Italy	290.79
Netherlands	1779.28
Norway	1551.66
Spain	18.93
Turkey	18.03
United Kingdom	492.25
Total Western Euorope	4566.47

EASTERN EUOROPE
& U.S.S.R.

Albania	17.14
Bulgaria	6.39
Czechoslovakia	12.53
Hungary	96.11
Poland	117.39
Romania	94.63
U.S.S.R.	44757.03
Yugoslavia	74.17
Total Eastern Euorope & U.S.S.R.	45175.40

MIDDLE EAST

Abu Dhabi	4675.19
Bahrain	153.71
Dubai	117.65
Iran	15354.22
Iraq	2429.67
Israel	0.26
Jordan	2.56
Kuwait	1227.62
Neutral zone	25.58
Oman	253.20
Qatar	4143.22
Ras al Khaima	30.69
Saudi Arabia	4707.11
Sharjah	273.66
Syria	163.68
Yemen	179.03
Total Middle East	33737.03

AFRICA

Algeria	2979.54
Angola	46.04
Benin	...
Cameroon	99.23
Congo	66.50
Egypt	317.14
Equatorial Guinea	21.48
Ethiopia	22.51
Gabon	11.51
Ghana	...
Ivory Coast	89.51
Libya	1099.74
Madagascar	1.79
Morocco	1.10
Mozambique	58.57
Namiba	53.71
Nigeria	2678.26
Rwanda	51.15
Somalia	5.37
South Africa	46.04
Sudan	76.73
Tanzania	104.86
Tunisia	76.73
Zaire	27.06
Total Africa	7934.55

WESTERN HEMISPHERE

Argentina	522.99
Barbados	0.15
Bolivia	115.09
Brazil	103.48
Canada	2474.02
Chile	104.86
Colombia	99.46
Cuba	2.56
Ecuador	99.36
Guatemala	0.26
Mexico	1828.85
Peru	180.95
Suriname	0.00
Trinidad & Tobaco	227.62
Venezuela	2813.30
United States	4329.92
Total Western Hemisphere	12902.86
Total World	104036.19

Annex (2)

Development of Natural Gas production

in the Arab World

Million Cubic Meters

Year	Total Production	Reinjected	Flared	Losses
1975	114 675	13905	67655	n.a
1978	149373	20072	80542	n.a
1981	171436	43493	47413	8283
1984	186367	57619	23519	16922
1986	212389	57400	25780	20569
1988	239390	65770	20660	22640
1990	269878	73004	24289	24904

Source : OAPEC SECRETARY GENERAL Reports
1976 , 1980 , 1985,1989

* Estimated .

* n.a : not available

Annex (3)

Technological Development For Electricity Generation by Natural Gas

Recent technological advances have permitted natural gas to become a more competitive baseload fuel . They most important advance is higher conversion efficiency in individual turbine systems . High efficiency gas turbine have become key components in industrial Co-generation systems and in combined - cycle systems for industry and utilities .

Developments in aircraft technology have led to such advances as heat - resistant materials, advanced cooling methods and component design changes. New gas turbine systems may have peak inlet temperatures as high as 1300 C , compared with 900 C previously , as well as a high ratio of outlet to inlet pressures in the compressor. Both factors, but especially the increase in temperature, can boost overall conversion efficiency to 35% or more from 30% in the previous generation, thus reducing fuel requirements .

Within ten years turbine inlet temperatures are expected to be around 1370 and pressure ratio around 16:1 .

Using a heat exchanger to recover some of the heat energy from the gas turbine exhaust in a steam generator can increase the global conversion efficiency in gas turbine systems . The most important application of heat recovery in gas turbines is the combined cycle systems , in which waste heat raises steam to drive a steam turbine. such a dual turbine system increases global conversion efficiency over 50% . By the turn of the century , combined cycle conversion efficiency is expected to approach 60% .

The combined cycle system can be flexible . The heat exchanger can be added to a peak load operated gas turbine for use when base load demand increase . In a cogeneration configuration, the recovered heat is used directly as industrial process heat , space heat or in an absorption cycle for air conditioning .

Source : International Energy Agency , Electricity supply in The OECD .

Annex (4)

Demand on Electrical Energy IN THE ARAB COUNTRIES

Peak Demand Forecast (MW)

Country	1995	2000	2015
Iraq	10900	18100	42000
Jordan	00820	01100	01700
Lebanon	01300	01700	02900
Syria	03300	04700	10600
SCECO Central	04800	05600	09400
Sceco South	01300	02200	05000
SCECO East	06000	06700	11000
SCECO West	06400	08500	18600
Egypt	09700	12600	23200
Kuwait	05900	07600	14700
Bahrian	01100	01400	02400
Qatar	01400	01800	02600
UAE	04400	04900	06300
Yemen	00400	00600	01400
Oman	01400	01900	02800

Energy Demand (GWH)

Country	1995	2000	2015
Iraq	57300	95200	220800
Jordan	09600	06000	010500
Lebanon	07200	09600	016100
Syria	18700	27900	066800
SCEEO Central	24700	30300	051000
SCECO South	07500	13200	029500
SCECO East	34900	40400	065900
Sceco West	37700	51700	101800
Egypt	54600	69700	125500
Kuwait	29200	37800	073300
Bahrian	05000	07100	011100
Qatar	07200	09100	014900
UAE	22100	24400	031500
Yemen	02100	02800	007500
Oman	06100	09900	011400

Annex 5

Assumptions Used in the Analysis of Generation Costs for Large Systems 2000 MW and UP

	Coal-Fired	Oil-fired	Combined-Cycle
Unit capacity (MW)	0600.0	0600.0	0450.0
Plant Factor(%)	0065.0	0065.0	0065.0
Energy production (GWh/Year)	3416.4	3416.4	2562.3
Total Capital cost (US$ Million)	0720	0600.0	0270.0
O&M cost (% of Investment cost)	0003.0	0002.5	0002.0
O&M cost (US¢/kWh)	0000.63	0000.44	0000.21
Fuel	Coal	Fuel Oil	Natural Gas
Fuel price (US$/MM kcal)	04.79	08.58	07.5
Thermal Efficiency%	37	38	47
Fuel Unit cost(¢/kWh)	01.0	01.9	01.4
Construction period (year)	05	03	02
Economic life(year)	25	25	20
Interest Rate(%)	10	10	10
Generation Cost(¢/kWh)	04.00	04.27	02.85

Assumptions used in the Analysis of

Generation costs for small Systems

Below 500 MW

	Combined Cycle	Coal-Fired Steam	Fuel-Oil Steam	Low -Speed Diesel
Unit capacity (MW)	90	100	100	90
Plant Factor(%)	65	65	65	65
Generated Energy (Gwh/Year)	512.5	569.4	569.4	512.5
Specific Capital Cost (US$/Kw)	700	1500	1300	1200
Total Investment (US$ Million)	63	150	130	108
Annual O&M Cost (% of Investment Cost)	2.0	3.0	2.5	2.5
O& M Cost (US ¢/Kwh)	0.25	0.8	0.6	0.5
Fuel	N.Gas	Coal	Fueloil	Fueloil
Fuel price (US$/MMkcal)	7.5	4.8	8.58	8.58
Thermal Efficiency%	47	37	38	40
Fuel Unit Cost (US ¢/Kwh)	1.4	1.0	1.9	1.7
Economic Life (year)	20	25	25	20
Inerest Rate(%)	10	10	10	10
Generation Cost [5 US¢/Kwh	3.1	4.7	5.1	4.7

Annex (6)

Sensitivity Tests on Large Systems

US ¢/ Kwh

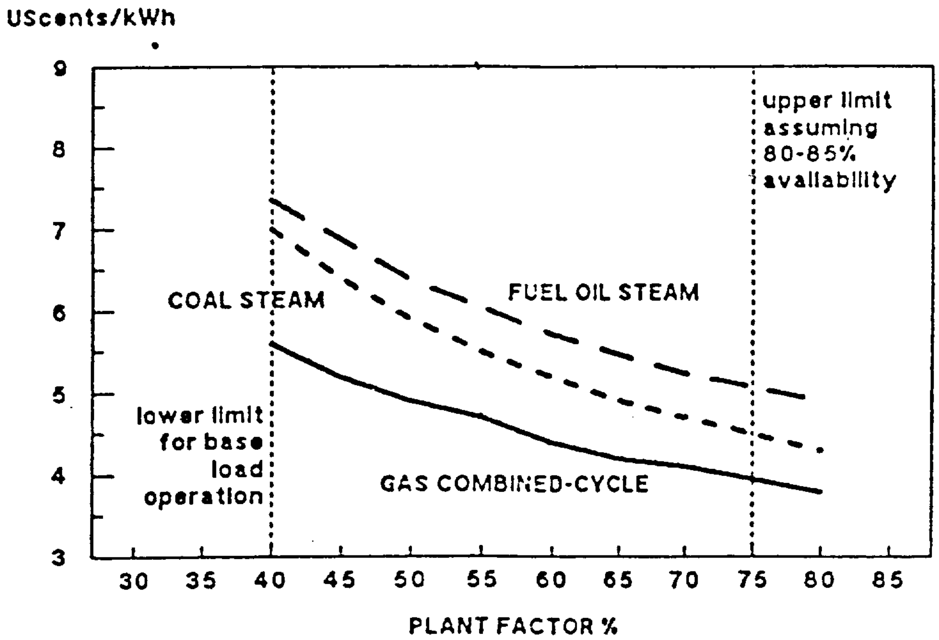
	Combined Cycle	Coal Steam	Oil Steam
Base Case	2.85	4.3	4.0
CC Investment cost + 25%	3.15	4.3	4.0
Gas Price + 50%	3.5	4.3	4.0

Sensitivity Tests on Small Systems

US ¢/Kwh

	Combined Cycle	Coal Steam	Oil Steam	Diesel Engines
Base Case	3.1	4.7	5.1	4.7
CC Investment cost + 25%	3.5	4.7	5.1	4.7
Gas Price + 50%	3.8	4.7	5.1	4.7

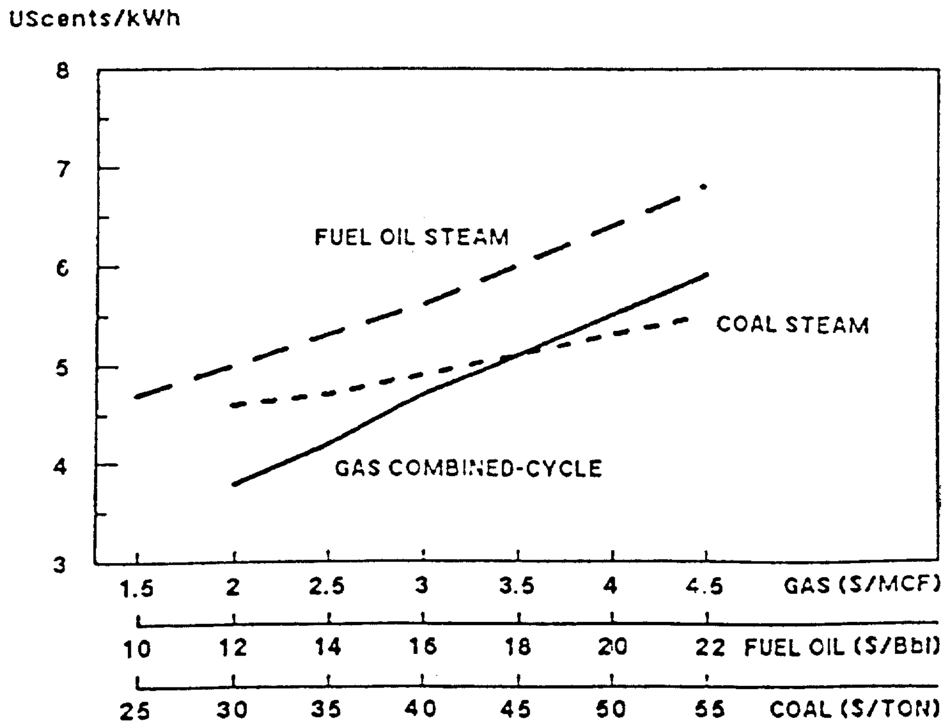
PLANT FACTOR IMPACT ON GENERATION COSTS FOR LARGE SYSTEMS



(FIG.12)

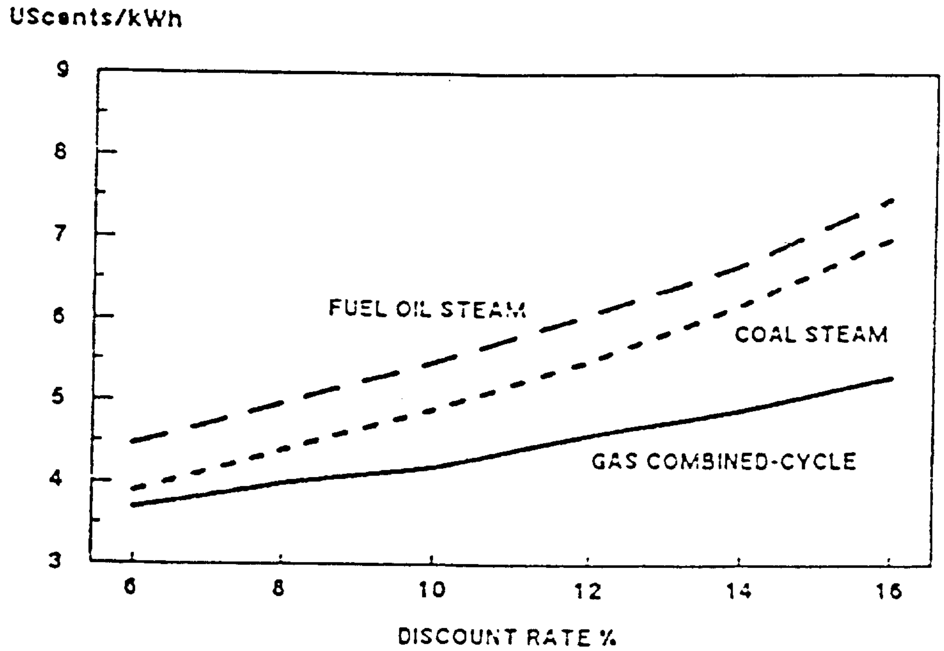
Sourlle:- EDWIN MOORE AND ENRIQUE (ROUSILLAT.REF.4
FIGS 13-17 ARE FROM THE SAME SOURCE.

FUEL-PRICE IMPACT ON GENERATION COSTS FOR LARGE SYSTEMS



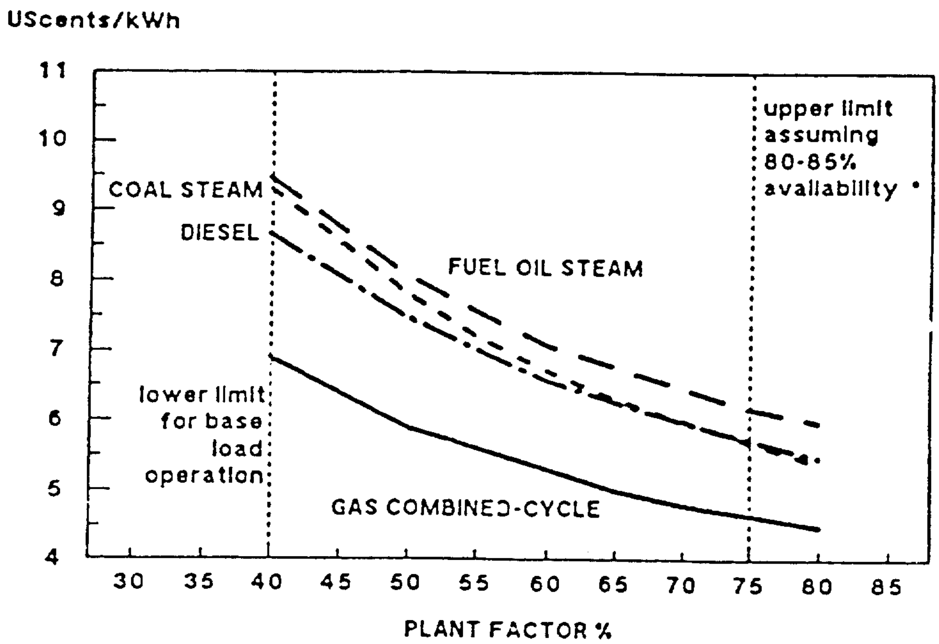
(FIG.13)

DISCOUNT RATE IMPACT ON GENERATION COSTS FOR LARGE SYSTEMS



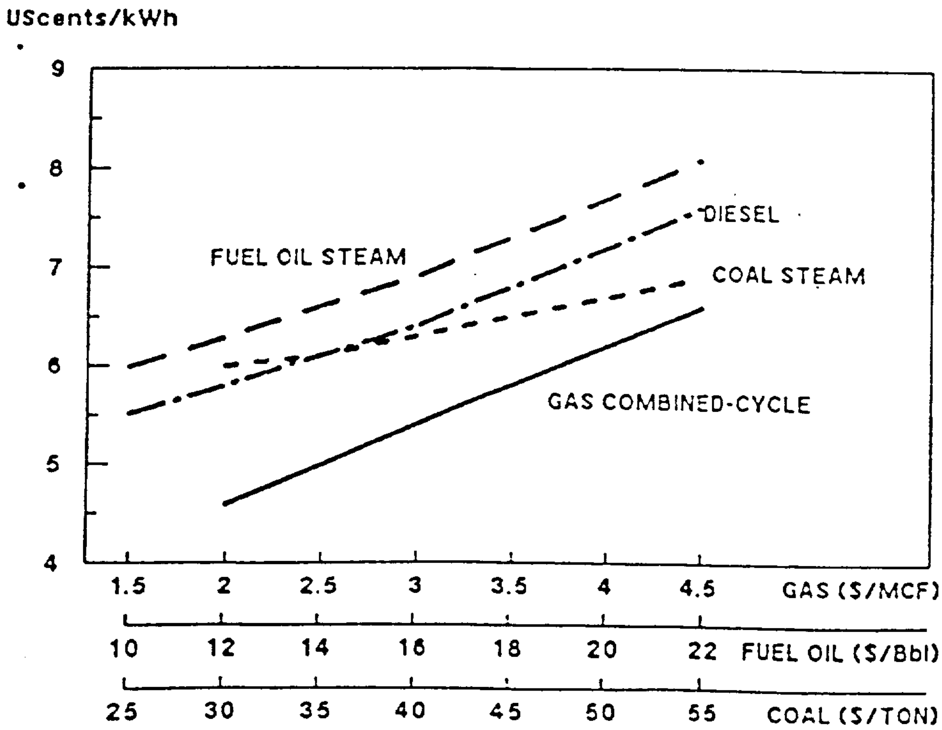
(FIG.14)

PLANT FACTOR IMPACT OF GENERATION COSTS FOR SMALL SYSTEMS



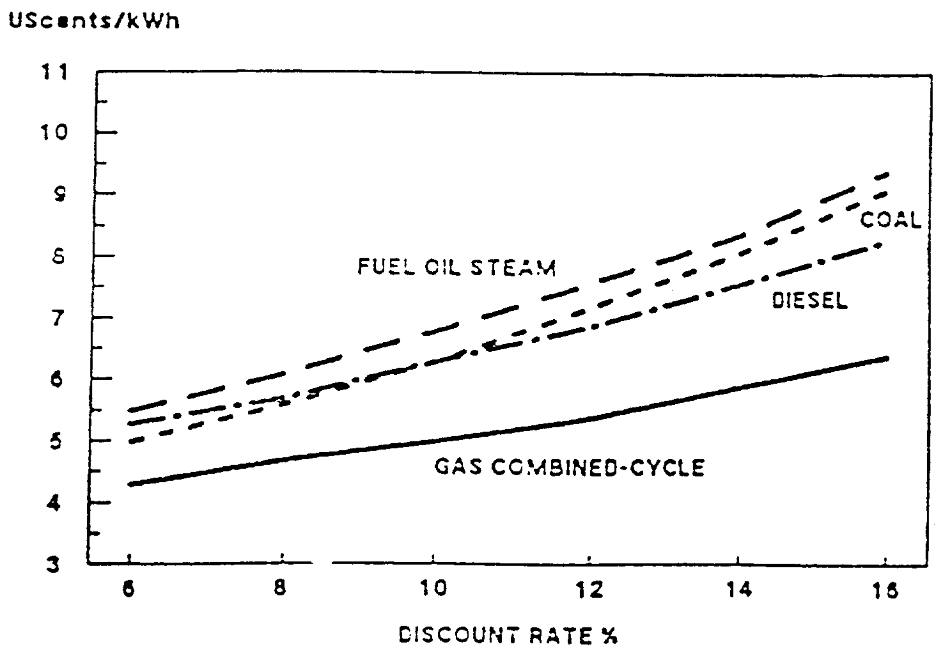
(FIG.15)

FUEL PRICE IMPACT ON GENERATION COSTS FOR SMALL SYSTEMS



(FIG. 16)

DISCOUNT RATE IMPACT ON GENERATION COSTS FOR SMALL SYSTEMS



(FIG.17)

Annex (7)

Gas Requirements for a 450 MW

Gas - Fueled Combined -Cycle Plant

1 - Assuming that the average annual plant factor will be 65% . The annual electricity Output of a 450 MW plant therefore would be about 2.5 TWh.

2 - Assuming the average lifetime thermal efficiency is about 45% , the energy requirement is 1910 Kcal per KWh. or 7.64 Cubic feet per Kwh .

3 - The annual gas requirement for a 450 MW Combined-Cycle power plant is therefore about 19 billion cubic feet per annum .

4 - The fuel requirement for the life of the 450 MW plant (20 years) is about 380 - 400 billion cubic feet .

Annex (8)

Gas Required for power Generation

In The Arab Countries

Million Cubic Meter

Country	1995	2000	2015
Iraq	11713	19463	45282
Jordan	921	1227	2153
Lebanon	1458	1969	3307
Syria	3836	5703	13717
Saudi Arabia	21323	27749	51076
Egypet	7468	14271	25641
Kuwait	5984	7723	15025
Bahrian	1023	1458	2256
Qatar	1483	1867	3077
UAE	4526	5000	6461
Yemen	434	564	1538
Oman	1253	2025	2333
Total	61432	89230	17871

Annex (9)

Gas Turbine Manufacturers

Firm	MW Range
AEG-Kanis	010 - 011
Allison (General Moters)	003 - 005
Alsthom	020 - 116
ASEA-Brown Boveri	048 - 146
Jhon Brown	010 - 116
Daihatsu	001
Fiat Aviazione	005 - 128
General Electric	026 - 202
Kawasaki Heavy Industries	001 - 003
Kobe Steel	001 - 006
Kongs berg Dresser	001 - 036
ASEA - Std	009 - 017
Cooper Rolls-Cobeerna	015 - 026
Deutz	001 - 005

Dresser . Rand	004 - 026
Garret	001
Hitachi Zosen	003 - 024
Ishikawajima - Hairma	004 - 055
Man GHH	005 - 011
Mitsui Engineering	001 - 150
NUOVO Pignone	005 - 120
Rolls - Royce	015 - 020
Ruston	001 - 035
Siemens	100 - 155
Solar	001 - 017
Sulzer - Escher Wyss	006 - 025
Thomasson	010 - 170
Westinghous Canada	025 - 050
Westinghouse	108
Niigata Engineering	001 - 008
Textron-Lycoming	001 - 003
Turbomeca Industrial	001

Source : 1988 Diesel and Gas Turbine World Wide Cataloque .

Annex (10)

Actual 1989 and planned 1999 Combined-Cycle

Capacity in The Developing Countries

Country	Capacity Actual 1989	MW Planned 1989
Ivory Coast	0000	0290
Nigeria	0000	1000
Bangladesh	0030	0210
Burma	0000	0180
India	0000	1900
Indonesia	0000	1500
Malaysia	0900	3840
Thailand	0772	2532
Egypt	0000	0540
Hungary	0000	0300
Pakistan	0600	1906
Syria	0000	2400
Tunisia	0000	0150
Yugoslavia	0000	0600
Mexico	1790	1870
Others	0085	0352
Total	4170	19570

Source : E.Moor and Enriq Crousillat, World Bank Industry and Energy Dept.

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