and environmental protection share of natural gas is expected to increase to 300% in 2050 compared with 19990.

3. Bearing in mind that developing countries, India, Pakistan, China, Latin America and South East Asia will have the highest growth in energy demand in future and if natural gas is to occupy its expected share in energy supply scenario, long distance transportation of natural gas should overcome its present hurdles.

4. Long pipeline transportation with multi countries network is both expensive and is politically vulnerable.

5. Production cost, liquefaction and transportation of natural gas is costly, but if the price of Brent crude stays above $17 U.S.A., it will be a viable project.

6. Well head to wire production of electricity, from stranded assets and Gas to Liquid Technologies, seem to be a good way of transporting inherent energy in natural gas. This may be a good option for the Persian Gulf area against other options.

7. Over-production of transportable modes of natural gas in the Persian Gulf area may be a hazard. Agreement on production sharing as in the case of crude oil among prospective natural gas exporting countries may be an advisable approach.

8. The chances of renewable sources of energy and nuclear power to have a significant share by the year 2050 in the supply scenario of the world energy scenario are slim.

9. If the price of oil stays above US$ 17 (Brent crude) as it is now, then, if the price of natural gas is increased to the right level, it is reasonable to expect that it will make it economically justifiable to put an end to gas flaring in some producing countries at marginal cases. Global Environmental Facility19 (GEF) on behalf of UNEP and UNDP and International Finance Cooperation20 can give assistance to stop gas flaring and thus reducing world CO2 emission.

10. Conversion of Diesel Engines to Diesel Dual Fuel (DDF) utilizing up to 80% natural gas will conserve energy and protect the environment21.

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Table XI
Benchmark Data for LNG Projects in the Middle East

Item	Section	QatarGas	RasGas	OmanLNG
Investment Costs	Upstream	1,200	835	1,300
(US$ million)	Downstream	2,800	1,700	1,800
External Finance	Upstream	0.55	0.75	0
Share	Downstream	0.70	0.75	0.8
Output	Gas (mcf/d)	830	660	950
	NGL (bl/d)	50,000	40,000	80,000
	LNG (mt per year)	6	4.8	6.6
Royalty	Gas	0	0	0
(share)	NGL	0.12	0.09	0
	LNG	0	0	0
Production Share	Gas	1	1	0
Government	NGL	0.23-0.45	0.23-0.45	0

The export activities for natural gas has to expand greatly in the short and long term scenarios

Fossil fuels reserves give good indications that they will play an important role in energy supply pattern of the world at least to the year 2050

Kuwait and Baghdad, with an expanded gas network boosting the capacity to 25.8 bcm/yr extending to Syria/Jordanian border and from there to Amman and Damascus. The cost of the whole scheme estimated to be 2.25 billion (1990$) with a length of 3000 km.

* Qatar-Europe Gas Export Scheme - 4900 km - 30 bcm/yr at a cost of $12 billion (1989$).

* Middle east Gas Loop - 6000 km (four segments) (Iran, Turkish-Syrian border through Turkey to East Mediterranean countries), a southern trunk line to run from Oman through UAE, and Doha in Qatar, and then to connect with the gasline to Kangan (under sea) to form a loop. The loop design would provide access to other sources such as Turkmenistan with a branch line to pipe gas until Austrian border with possibility of joining to European network. Its capacity is 28 bcm/yr, 48/36 in (1.22/091 m) would cost about $10 x 109.

Discussion Summary and Conclusion

The World population will increase in the 21st century and together with higher standard of living means higher energy demand in the 21st century.

1. Even with higher efficient technology of energy usage the demand for energy in 2100 will be 3.355 times that of energy usage in 1990. Fossil fuels reserves give good indications that they will play an important role in energy supply pattern of the world at least to the year 2050.

2. Considering availability of fossil fuel and implementing decarbonization

Table IX GTL Plant				
Plant Lost Energy %	45.0			
			T Btu/y	bbl/day
Plant Outlet Synfuels Capacity			57.09	30,000
			20 % Naptha and 80 % diesel	
Unit Capex per 30,000 Bpd of Synfuel, US$/Bbl x day	30,0 00			
Plant Capex escalated per power of, US$ 0.7.5 million	900			
Plant OPEX % of Capex	5.8			
Plant OPEX, US$ per million/year	52.2			
		Capex	Opex	Total
Unit Production Cost, US$/bbl		10.68	5.27	15.95
Unit Feedgas Cost per 1 bbl of Synfuel, US$/Bbl				6.29
Total Unit Industrial Cost, US$/Bbl		10.68	5.27	22.24
Diesel/naptha are sold in the market at US$ 22.24/bbl when Brent price is US$ 16.68/bbl				

They produce high revenue streams over two or three decades, which can provide the cushion for short term fluctuationsin other parts of the business.

Table X LNG Projects Currently Under Construction			
Project	Trains	Capacity (in mt/a)	Start-up Date
Nigeria LNG	2	5.7	1999
Bontang (Indonesia)	1	2.7	2000?
Atlantic LNG (Trinidad)	1	3.0	1999
Oman LNG	2	6.6	2000
RasGas (Qatar)	2	5.0	1999
Total		23.0	

Pipelines

As was mentioned earlier, due to higher energy demands in developing countries pipeline construction to supply oil and gas from exporting countries with special emphasis on Latin America and Asia-Pacific has to increase. Table X shows pipeline construction in 1996 and beyond.

As can be seen of the total of 27,069 miles (43,310 km) of gas pipelines of different diameters only 1,213 miles (1,940 km) is attributed to Middle East and Central Asia and CIS which have the highest proven gas reserves and largest potentiality for export to India, Pakistan and Asia-Pacific and Europe. There are 40 Asian pipeline development, installed lines would total more than 19,000 (30,000 km) with an estimated combined cost of $100 billions. Large capital cost for pipeline development is surely the biggest constraint for supply of natural gas from potential exporting countries to consuming countries.

Furthermore, as was the case for LNG project, gas export by pipeline is a long-term project between countries and companies which have to be involved in long term economic and politicalcommitments. Many times the involvement is not between one country but many when the nature of the project is to have many transit countries. Because of political and economic constraints problems the following projects in supply of natural gas from M.E. and Central Asia to Europe have been

* either abandoned or stalled16.

1680 km $1.50 billion (1990$) with a capacity of 20.67 bcm Persian Gulf East Mediterranean Network, 60% Qatar and 40% Abu Dhabi gas to Bahrain,

Table VIII
Analysis of Economical Convenience Between LNG and GTI

Common Input Data					
		MMscf/d	Mmt/y	Bcm/y	T Btu/y
Feedgas		300	2.1	2.8	103.8
No.of Production/year	20				
Operating Days/year	330				
Gas Feedstock Price, US$MMBtu	0.60				
IRR real %	10.0				
LNG Plant					
Plant Lost Energy %	12.0				
		MMscf/d	Mmt/y	Bcm/y	T Btu/y
Plant Outlet LNG Capacity		300	2.1	2.8	103.8
Unit Capex per 3.0 Mmtpa, US$/ton	350				
Plant Capex, escalated with power of US$0.65 million	765				
Plant OPEX % of Capex	3.5				
Plant OPEX, US$million/year	26.8				
Capex 1 Ship of 13,0000m^3, $ million	210				
No.of Ships, depwnd on distance/quantity (2 ships per 3 Mmtpa)	1.2				
Total Ships CAPEX, US$ million	258				
Yearly Opex Ships @ 3%	7.7				
		Capex	Opex	Total	%
Unit production Cost, $MMBtu		0.98	0.29	1.28	54
Unit Feedgas Cost/1 MMBtu of LNG $MMBtu				0.68	29
Unit Ship Transport Cost, US$MMBtu		0.33	0.08	0.42	18
Total Unit Industrial Cost, CIF US$/MMBtu		1.32	0.38	2.37	100
US$2.37/MMBtu LNG Market Price corresponds to a Brent Price of US$16.25/Bbl					

growth has slowed down. South Korea was until recently regarded as a hungry new market for LNG, but the financial crisis hitting the Asian region at the end of 1997 has thrown demand projections back. This comes at a time when 23 million tons of LNG capacity are under construction, as shown in Table X. With some time lag, LNG plants at various stages of the planning process could add another 50 million tons per year to the market within a decade or so. Looking at the years ahead for the LNG industry, the risks are certainly considerable, but the potential rewards are high. Natural gas is the energy source of the future, and some creativity and effort will be needed to take advantage of that. It should always be remembered that natural gas requires more long-term, strategic thinking than oil. People in the international natural gas companies should not tire of pointing this out to their colleagues and boards. LNG projects are the cash cows of the industry, once they have been carefully planned, marketed, and built.

Table V		
World's Major Gas Reserves[12,13]		
Country	Est. proved reserves tcf	Share, %
C.I.S.	1977.0	39.70
Iran	741.6	14.89
Qatar	250.0	5.02
Abu Dhabi	188.4	3.78
Saudi Arabia	185.4	3.72
U.S.	162.4	3.26
Venezuela	130.4	2.62
Algeria	128.0	2.57
Nigeria	120.0	2.41
Iraq	109.5	2.20
Canada	79.2	1.59
Norway	70.9	1.42
Mexico	69.7	1.40
Malaysia	68.0	1.37
Netherlands	66.2	1.33
Indonesia	64.4	1.29
China	59.0	1.18
Kuwait	52.4	1.05
Libya	45.8	
Pakistan	27.5	
Bangladesh	25.2	
India	25.0	
Oman	22.2	9.20
United Kingdom	22.2	
Australia	19.6	
Egypt	19.3	
Argentina	18.2	
Subtotals	4747.7	95.33
	232.6	4.67
Total	4980.3	100.00

gases (specially flared gases) for power generation.

LNG and GTL(17)

While at present time, LNG is a proven and mature technology, gas to liquids (GTL), that is, the chemical conversion of natural gas into liquids, such as syncrude or medium distillates (naphtha, jet fuel, diesel and lubricating bases) - remain a technology which require sometime to become mature. GTL technology which is the conversion of natural gas to CO and H2 and then to liquid hydrocarbons produces marketable products.

According to this analysis, both LNG and GTL have more or less the same economic results. To be precise, they are both convenient if the Brent crude reference price is in the range of US$ 16 - 17/bbl, and the price of feed gas is in the range of US$ 0.60/MMBTU. A feed gas price of US$ 1.0/MMBTU corresponds to US$ 20/bbl of Brent crude.

Financial Risk and Reward in LNG and GTL Business(18)

Currently, a total of 90 million tons per year of LNG is produced in the world. With almost 60 per cent of the total, Japan is the biggest importer of LNG, followed by South Korea. Japanese gas demand has been the engine of growth for the industry over the past three decades. It is no longer fulfilling this role as markets are becoming saturated and economic

Table VII	
Natural Gas, Reserve Production ratios	
C.I.S.	77
Iran	746*
Qatar	No major production
Abu Dhabi (UAE)	222.8
Saudi Arabia	165
U.S.A.	8.2
Venezuela	156.5
Algeria	72
Nigeria	No major production
Iraq	No major production
Canada	13.5
Norway	73.6
Mexico	51.4
Malaysia	93.2
Netherlands	23.9
Australia	19.7
Rest of the World	40.5
*570[14].	

Natural gas is the main energy source of the future.

Natural Gas Reserves and Production

Table V shows the world estimated proved gas reserves and Table VI shows 20 top producing countries12,13.

Table VII which gives respective reserves production ratios depicts the countries with higher export potential.

Combining the information with the expected share of natural gas in future supply and demand of the world (Table III) and the reality of higher growth share of energy demand in developing countries (India, China, South East Asia, etc.) and the advantages of natural gas (environmental and higher thermal efficiencies achieved over crude oil and coal Fig. 418 for new-gas fired combined cycle thermal power plants) one would expect that the export activities for natural gas has to expand greatly in the short and long term scenarios. The expansion of natural gas supply needs export infrastructures, i.e. long pipe line or LNG facilities. The challenges for expanding natural gas export infrastructure are many-fold, economic and political factors are the main constraints of the issues. These constraints are dealt with below.

5. Expanding Usage and Export of Natural Gas

5.1 Gas for Power Generation (W-W)(16)

The commercial development of stranded assets described as "Wellhead to Wires (W-W)", and principally relating to the following three market segments:

* Flared or associated gas from rice field;

* Natural gas fields which are close to depletion; and

* New gas fields for exclusive or main use of natural gas in power generation.

The W-W potential is estimated to be 86 GW or about 8% of the forecasted total world power generation capacity (including thermal generation, diesel, hydro) constructed between 1996 and 2010, and about 33% of forecasted gas fired additions worldwide.

Middle East and Africa (members of OPEC) have 20% of the world W-W potential.

Highly efficient, environmentally friendly and reliable power generation based on gas turbine technology and highly efficient and reliable power transmission system over long distances, such as high voltage D.C. systems, makes W-W technique a feasible approach for utilization of well head

Table V

World's Major Gas Reserves[12,13]

Country	Est. proved reserves tcf	Share, %
C.I.S.	1977.0	39.70
Iran	741.6	14.89
Qatar	250.0	5.02
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Saudi Arabia	185.4	3.72
U.S.	162.4	3.26
Venezuela	130.4	2.62
Algeria	128.0	2.57
Nigeria	120.0	2.41
Iraq	109.5	2.20
Canada	79.2	1.59
Norway	70.9	1.42
Mexico	69.7	1.40
Malaysia	68.0	1.37
Netherlands	66.2	1.33
Indonesia	64.4	1.29
China	59.0	1.18
Kuwait	52.4	1.05
Libya	45.8	
Pakistan	27.5	
Bangladesh	25.2	
India	25.0	
Oman	22.2	9.20
United Kingdom	22.2	
Australia	19.6	
Egypt	19.3	
Argentina	18.2	
Subtotals	4747.7	95.33
	232.6	4.67
Total	4980.3	100.00

Table VI

World's Top 20 Gas Producing Countries: 1994[12,13]

Country	Production, bcf	Share, %
C.I.S.	25 673.8	33.3
U.S.	29 822.0	25.7
Canada	5855.1	7.6
Netherlands	2771.8	3.6
United Kingdom	2539.8	3.3
Indonesia	1852.6	2.4
Algeria	1779.0	2.3
Mexico	1323.0	1.7
Saudi Arabia	1119.7	1.5
Iran	994.6	1.3
Australia	997.0	1.3
Norway	947.1	1.2
Venezuela	834.0	1.1
United Arab Emirates	845.7	1.1
Romania	687.2	
Malaysia	729.4	
Italy	718.2	5.2
Germany	654.4	
Argentina	615.7	
India	600.7	
Top 20 Total	71 360.8	92.6
Others	5671.3	7.4
Total	**77 032.1**	**100**
* 1300 bcf		

If the major abatement measures (carbon tax) are implemented the share of the fossil fuel will have to be reduced by 2050 (lower range of Table II, or even lower). A decline in the use of coal specifically and crude oil to some extent which have a much higher CO2 emission than natural gas, Fig. 2.b.11 Appendix, would be expected and natural gas would have a higher share to almost three times in 2050.

Figures 3(a)6 and 3(b)6 show sulfur dioxide and carbon dioxide emissions (2% S coal), for several scenarios.

Table III				
World Primary Energy Supply/Demand Projections (10^6 toe)[3] and CO_2 Emissions (10^9 tonnes of carbon)				
	Year			
	1990	2000	2010	2050
Energy demand	8045	(10^6 toe) 8570-9300	9800-11160	18100-21000
Energy supply				
Oil	3185	3400-3500	3800-3900	5400-5800
Coal	2258	2200-2600	2700-3200	4000-5000
Gas	1596	1870-2000	2000-2500	5000-6100
Hydro, nuclear & others	1006	1100-1200	1300-1560	3700-4100
Fuel shares		Percentage		
Oil	40	40-38	39-35	30-28
Coal	28	25-28	28-29	22-24
Gas	20	22-21	21-22	28-29
Hydro, nuclear and others	12	13	13-14	20
		(10^9 tonnes of carbon)		
CO2 emissions	6.5	701-7.7	8.0-11.0	13.0-15.0

undertaken to enhance green house gas sinks and reservoirs

The controlled CO2 emission scenario after 2050 implies not future increase in atmospheric CO2 concentration.

Four organizations (IAEA, IIASA, OPEC, and UNIDO). Collective views on the future supply and demand situation, and CO2 emission are presented in table III.

The basic assumptions in both medium-term projections are related to the development of the oil prices, growth domestic products (GDP) and energy intensity.

It is assumed that oil prices will remain constant in real term as US$21/bbl (1991) and will only increase with inflation, average world GDP growth will be 2.9 per cent and world energy demand will grow by 1.8 per cent and 1.6 per cent for the period 1990-2000 and 2000 to 2020, respectively.

Energy intensity (boe/US$1000 GDP) in OECD countries will be reduced from 2.99 in 1991 to 2.22 in 2010, while the energy intensity for the world as a whole,(excluding the former centrally planned economies) is projected to decline from 3.22 in 1990 to 2.55 in 2010. As can been seen if the worries about the atmospheric impact of increasing CO2 concentration persist, the burden of global energy problem should shift from developed to developing countries (see Fig. 1 and Table IV)

Table IV								
Summary of Current and Estimated Energy Use in the Year 2100[6]								
Country group (KOE/CAP)	Energy use in 2100 (exajoules)	% of each group in year 2100	Energy use in 1990 (exajoules)	% of each group in year 1990	Energy factor	Population factor	Per capita energy factor	% of energy use due to population
0-200	151.27	13.44	2.60	0.77	58.22	4.56	12.77	26.30
200-400	226.12	20.09	13.63	4.06	16.59	2.38	6.96	25.52
400-800	224.72	19.96	34.05	10.15	6.60	1.66	3.98	29.44
800-1600	148.15	13.16	23.86	7.11	6.21	2.22	2.80	44.23
1600-3200	81.15	7.21	26.10	7.78	3.11	1.78	1.75	50.40
3200+	294.17	26.13	235.30	70.13	1.25	1.12	1.11	50.18
Total	1125.59	100.00	335.53	100.00				
Total world commercial energy use in 2100 is estimated to be in the range of 1100 exajoules for reasonable expectations of improved efficiency and average growth rates and 910 exajoules for lower growth expectations. [1 exajoule ≈ 22.4 x 10^6 (toe)].								

Environment Constraints and their Impacts on Energy Options in the 21st Century

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1. Introduction

In the year 2100 the world population is forecasted to be 11.3 billion of which Africa and the Developing countries will have the highest growth rate. This together with expected highest standard of living means that the world energy requirements will be astronomical in the future. Satisfying those requirements while minimising global carbon dioxide output may well be the most formidable challenge in the 21st century. In this connection the paper outlines the strategies for satisfying the global energy requirement and explain what should be the portion of natural gas, a premium low producing CO2 source of energy in the world energy pie and what would the constrains in meeting its share. Energy particularly energy derived from fossil fuels will continue to play a prominent role in the driving force of the global economy since their reserves are abundant and would last for many decades, ultimate availability of energy resources and the size of recoverable fossil energy resources change with price levels, recovery technology development, transport technology for long distance natural gas transmission, geopolitical conditions, etc.

Table 1 shows that the cumulative production of resources has not reached an appreciable level of the original reserves of each energy source. The position of natural gas against crude oil shows a larger R/P ratio for both the identified and ultimate reserves.

2. World population: Present and the future

The present and predicted future population of the world is given in Table II, and Figure 1.a. Appendix. This is a very optimistic forecast as far as the ability of the world in population growth is concerned, there are presently many global incentive in place to control the population. Even then as can be seen from the table the developing countries which accounts for 77 per cent of the world in 1990 will account for 88 percent of the total world population in the 2100.

3. Energy, Supply and Demand

World demand for both energy services and supplies will continue to increase for sometime yet. The increase will be governed mainly by economic growth in the medium term and population growth in the longer term. Energy consumption will increase more in developing countries than in industrial countries, figure 1.b. Appendix, based on 2-to-3 percent per year global economic growth.

Assuming energy efficiencies yielded by measures taken to reduce environmental impact figure 2.a. Appendix, two scenarios for two time horizons, medium term covering period of 2010, and long term extending to 2050, are considered and two energy supply actions are assumed for each scenario, i.e. (i) a dynamics as usual scenario and (ii) a controlled CO2 emission SO2 as well to be considered.

The dynamic-as-usual scenario assumes that the past and present trend will continue with no major environment restriction reducing or reversing world energy demand, for the period 1990 to 1010. The controlled CO2 emission scenario assumes that by 2010, only the OECD region will have stabilised CO2 emission at 1990 levels, some developing countries will continue to consume energy at the rate assumed in the dynamic-as-usual scenario. In practice, if the concerns about climate change prove to be correct, remedial measures will have to include all green house gas sources, including methane (with emphasis on coal mining operation) and parallel efforts will have to be