Energy Permanent Monitoring Panel of the World Federation of Sciences

Erice – Sicily

19th August 2004

ENERGY CONSIDERATIONS – GLOBAL WARMING PERSPECTIVES

Dr Hisham Khatib

Honorary Vice Chairman – World Energy Council

(Draft – 11th August 2004)
(Ideas expressed are entirely personal)

INTRODUCTION

Nodoubt energy is a major anthropic cause of what is termed as "green-house gases" particularly carbon. Fossil fuels which account for over 85% of commercial global primary energy consumption are rich in carbon at varying degrees (coal is over rich, natural gas is less rich). Human usage of energy and its dependence on fossil fuels have not changed during the last few decades and are unlikely to change for decades to come. In the foreseeable future, there is no alternative to fossil fuels, to satisfy global energy needs.

New renewable energy sources, other than hydro, does not contribute more than 2% of global resources (only less than 1% if refuse is not included) and is not likely to significantly increase its relative contribution for years to come. Such renewable sources are intermittent and disbursed correspondingly they are expensive and unreliable. Fossil fuels are abundant, highly concentrated, versatile and efficient, correspondingly they are relatively cheap and tradable. Geographical endowment is not even (particularly in case of oil), this creates serious worries about security of supplies, but experience of the last few years have proven that such worries are exaggerated (and unjustified).

A concerted global action to restrain emissions is still to come. Kyoto Protocol, although agreed seven years ago, is still to be ratified. The US decided to withdraw and Russia is wavering. The main problem is that the cost to national economies (and the global economy) of restraining emissions and of enforcing a strong carbon discipline and developing alternatives are severe and involves considerable cost. The rewards are doubtful and long term.

The problem is compounded by the fact that the major part of increase in future emissions will come from developing countries, particularly countries with high population concentration and high growth – China and India. Developing countries are eager to achieve economic growth and less worried about global warming. To convince these countries to join global carbon emissions restraint effort is not going to be easy, and without their participation the outcome will be limited. This is a serious dilemma.

Global warming as a science is still controversial. It is not the intention of this paper to dwell on the controversies. But calls for efforts to restrain emissions are becoming stronger and almost universal. They are concerned with: better energy efficiency, clean technologies (fossil and non fossil), switching to cleaner fuels and involving developing countries. We shall start with the last issue being the most important in the long term.

Developing Countries and Global Warming

DCs are going to be the main player in the growth of the global energy market in the coming decades. Lead by china (and to a lesser extent India) their energy demand which accounted for only one third of global primary commercial energy in 2003 (it was only 27% in 1993) will surge to 43% in 2025. It will near half world consumption by 2030. Correspondingly DCs will, as a group, be the main emitters of CO_2 in the coming years as detailed in the following table.

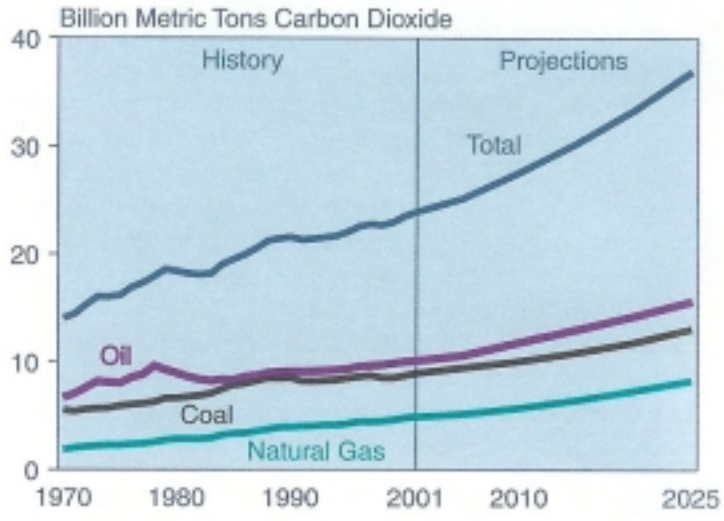
Carbon Dioxide Emissions
% ge contribution

	2001	2025
Industrialized Countries	49 %	42 %
DCs	38 %	46 %
EE / FSU	13 %	12 %

Note: DCs energy carbon intensity is higher than OECD.

This however should not obscure the fact that all the three groups will be increasing their carbon emissions in the next many years as shown in the following graph, which projects the rising global CO_2 emissions.

Figure One
Global CO_2 Emissions



Source: Energy Information Administration (WIA) *International Energy Outlook 2004 (IEO 2004).*

This is promoted by the following factors:

(1) Rapid Economic growth

Most DCs, particularly the countries in South Asia – China, India, Indonesia, ..., have experienced and continue to have high economic growth. Because of high population increase and fact that they are in the early stages of their development they have the potential for more rapid growth. This also implies that their economic development is more energy intensive than the mature economies of the industrialized countries. The following two tables give indications of past economic history and future trends, also of the extent of energy intensity.

Global Economic Growth

Annual Growth %		
	1977 – 2001	2001 – 2025
Industrialized Countries (ICs)	3.0%	2.4 %
Developing Countries (DCs)	4.8 %	4.6 %
China	8.2 %	6.1 %
India	4.9 %	5.2 %
East Europe / FSU	- 2.9 %	4.1 %
World	3.3 %	3.0 %

Source: WEO (2002), IEO (2004).

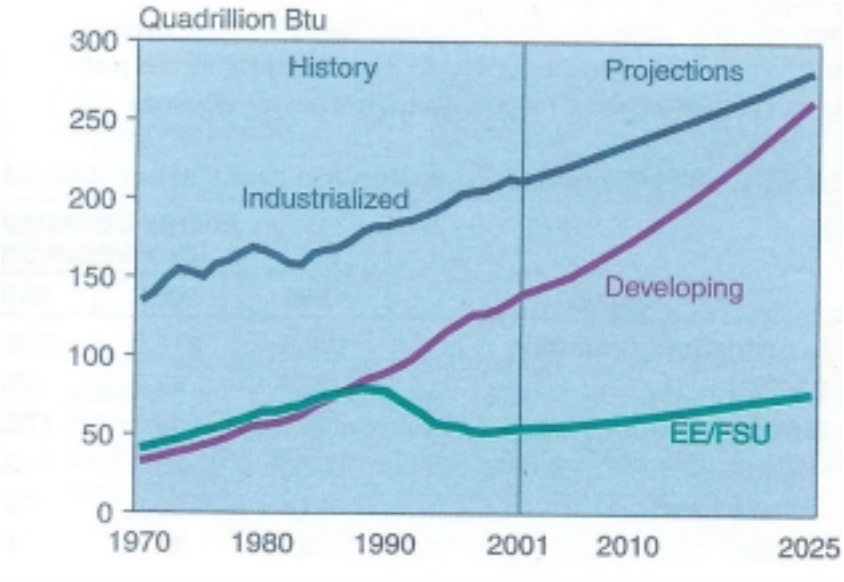
Energy Intensity

Energy Intensity 1000 BTU / $ GDP (1997)			
	1977	2001	2025 (e)
Industrialized Countries (ICs)	13	8	5
Developing Countries (DCs)	23	22	14
East Europe / FSU	45	50	30

Source: IEO (2004)
Note: By 2025 DCs will not even attain the level of energy efficiency that OECD achieved 50 years ago.

These two tables are very significant in indicating trends in global energy consumption. DCs income is expected during the next few years to increase at twice that of the rate of industrialized countries and because of the high energy intensity in DCs (almost 3 times that of ICs), DCs energy consumption is expected to equal that of ICs by the year 2030 as is shown in the following figure.

Figure Two
Energy Consumption



Source: Energy Information Administration (WIA) *International Energy Outlook 2004*

Also because of the high carbon intensity of fuels utilized by DCs (mainly coal in China and India), DCs carbon emission, will almost certainly constitute almost half of global emissions by year 2030. From all the above it is clear that any global effort which does not have containment of carbon emissions from DCs as its center of interest will be missing the target.

RESTRICTING FUTURE EMISSIONS – The Way Ahead

Future carbon emissions can be significantly restricted by regulations, efficiency measures and technology. There are (beside the Kyoto mechanisms many ways to restrict emissions) these are mainly, but not restricted to the following

(1) Better and higher efficiency in energy use.
(2) Electrification and fuel switching with more reliance on natural gas
(3) Resurgence of nuclear power.
(4) Greater use of new and renewable energy.

We shall now explore these measures in greater detail.

Efficiency in Energy utilization

Continuous improvement in energy utilization has been taking place in the industrialized world, and to a lesser extent in DCs, all through the last three decades with remarkable results. In the past economic growth was accompanied by a commensurate increase in energy use. Coupling was almost one to one. With the oil shock of 1973, energy efficiency became a major issue and decoupling was achieved.

Over the period 1990-2001, world economy (world domestic GDP) grew by 31.5%, i.e. 2.52% annually. Simultaneously world total primary energy consumption growth was restricted to only 16%, i.e. 1.35% on the average annually. This signifies an average annual improvement of 1.2% in energy efficiency annually which is quite significant. Similar improvements are expected in the future. The US Energy Information Administration (EIA) expects future efficiency improvement to be no less than that of the past, 1.2% annually (3% economic growth versus 1.8% energy consumption annually). Without this the global CO_2 emissions of 23 900 million metric tons in 2001 would have been almost 48 600 million tons in 2025 instead of 37 000 million metric tons. An improvement of almost 11 600 million metric ton (i.e. reduction by one quarter) is expected to be achieved though better efficiency, during the first quarter of this century.

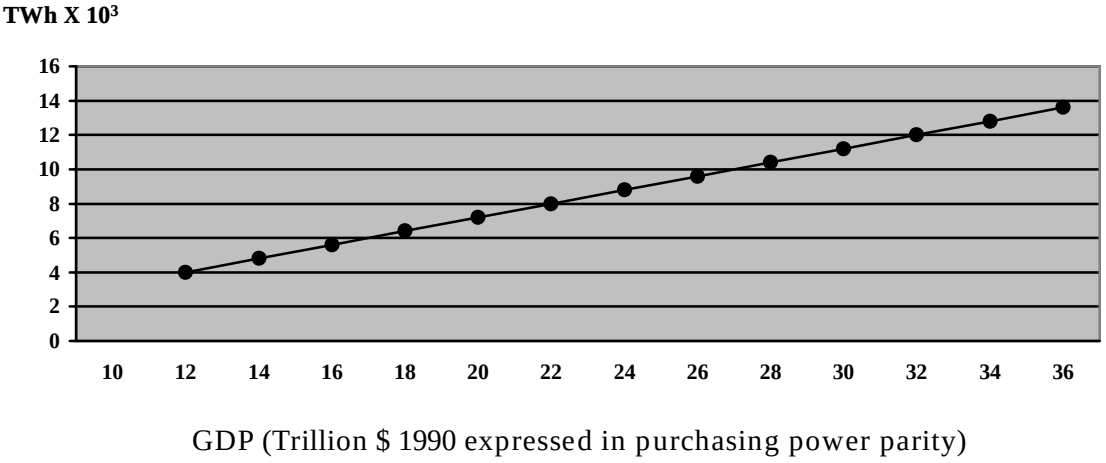
Value of Electrification

Electricity is versatile, clean to use, easy to distribute and supreme to control. Just as important, it is now established that electricity has better productivity in many applications than most other energy forms. All this led to the wider utilization of electricity and its replacement of other forms of energy in many uses. Demand for electricity is now growing globally at a rate higher than that of economic growth and in many countries, at almost 1.5-2 times that of demand for primary energy sources. Going electric will significantly contribute towards less carbon emissions.

The future is going to show a growing role of electricity as the preferred energy carrier. Growth in electricity use has been during recent years

markedly higher than energy demand growth and almost identical to that of economic growth, approximately 3% annually, (Figure 3). Of course such a trend cannot go on indefinitely. Electricity demand growth, will gradually slowly depart from economic growth as substitution and markets mature.

Figure 3
Electricity Demand as a Function of World GNP (Excluding Former CPEs)



Source: Khatib, H. *Economic Evaluation of Projects in the Electricity Supply Industry*, 2003.

However with the type of technologies and applications that already exist, there is nothing to stop electricity's advancement, nor it assuming a higher share of the energy market. Saturation of electricity use is not yet in sight, even in advanced economies where electricity production claims more than half of the primary energy use. Other than for the transport sector, electricity can satisfy most human energy requirements. It is expected that, by the middle of the 21st century, almost 70% of energy needs in some industrialized countries will be satisfied by electricity (Gerholm).

In the near future, electricity demand growth is expected to match the growth of the world economy. This is expected to average around 2.5-3.0% annually during the next few years. The International Energy Agency and the International Atomic Energy Agency (IAEA, 2002) estimate that global electricity production will increase at an annual average rate of 2.7-3.0% during the first decade of the 21st century. Therefore it is expected that total electricity production in 2010 will amount to around 20,000 TWh and in 2020 to 25,880 TWh. Most of this growth is going to occur in developing countries, particularly in south-east Asia, a region that is enjoying a rapid economic growth. In 2030 global electricity production is expected to exceed 28,000 TWh. half of this amount will be accounted for by developing countries.

No where better efficiency is achieved than in electricity generation. The average world efficiency of existing power stations is around 31%. New combined cycle gas turbines CCGT has an efficiency approaching 60%. A new modern CCGT plant firing natural gas would emit only 40% of a similar large modern coal power station which has a high efficiency around 42%. By going electric the world economy is restricting its carbon emissions.

Correspondingly electrification and its utilization of natural gas are going to be significant contributors towards containing global warming prospects.

Role of Nuclear Power

Inspite of its major contribution to the curtailment of carbon emissions, nuclear power contribution to global energy supply is on the decline. Nuclear power which is producing 16% of world electricity now is expected to see its share declining to 11% in 2025 and even less afterwards.

Accidents at Three Mile Island in the United States in 1979 and at Chernobyl in the Soviet Union in 1986 pushed public opinion and national energy policies away from nuclear power as a source of electricity. In the United States, massive cost overruns and repeated construction delays – both caused in large part by regulatory reactions to the accident at Three Mile Island – essentially ended U.S. construction of nuclear power plants. Similarly, both before and after the Chernobyl accident, several European governments had announced their intentions to withdraw from the nuclear power area. Sweden committed to a phase out of nuclear power in 1980 after a national referendum. Both Italy and Austria have abandoned nuclear power entirely, and Austria has also been a strong opponent of nuclear power programs in Eastern Europe that it considers to be unsafe. Belgium, Germany, and the Netherlands have committed to gradual phaseouts of their nuclear power programs, although in some cases such commitments have proven difficult to carry through. Given the periodic changes in political leadership that can shift official government positions on nuclear power, it is difficult to assess the degree to which current commitments for or against nuclear power will be maintained. Many issues still may impede the expansion of the nuclear power industry. Nuclear waste disposal remains a key concern. So are the dangers of proliferation and grave operational accidents in developing countries.

But also the future of nuclear is frustrated by its economics, although it does provide a measure of energy security, however its costs are high compared to CCGT plant firing gas. Nuclear, being capital intensive investment, is for government owned utilities and industries to undertake. Private business

which is increasingly taking over production of electrical power is not prepared to put the huge capital and undertake the high risks which nuclear entail. Correspondingly at least in the foreseeable future, nuclear power contribution to solve global warming problems will continue to be limited, and much less than its potential.

Biomass and Renewable Energy and Biofuels – Prospects for New Energy Sources

Biomass, whose contribution to global primary energy sources is significant, is not usually accounted for in global primary commercial energy consumption. However there are at least 2.40 billion people (i.e. as high as 40% of world population) is entirely dependant on biomass as their main source of energy. Biomass consumption in the world is around 1200 – 1500 m.t.o.e. (around 14% of global end use energy consumption). Biomass, which is mainly used in DCs (mostly Sub-Saharan Africa and South Asia), is a major source of local environmental degradation and emissions that injure public health.

Globally, the extraction and burning of biomass releases carbon dioxide into the atmosphere; however, there is no net release of carbon dioxide if biomass is planted and harvested at the same rate, because growing plants remove and sequester carbon dioxide from the atmosphere. But this is subject to questioning. What about the burning of dung for instance?

Prospects for the rise of new energy sources in the years to come are not promising, mainly because existing energy resources (particularly fossil fuels) are abundant, highly concentrated, cheap and tradable. The alternatives, particularly new and renewable energy are disbursed, intermittent and correspondingly expensive. No doubt some of the new energy sources like wind power are becoming competitive and certain applications of solar energy for water heating in sunny countries and for small electricity production by PV cells are becoming common. But this is only a small niche in a very large market.

The outlook for wind and solar energy is for double-digit growth, based on both continued public subsidies and technological advances. However, because they start from a very small base, their combined contribution to total energy supplies is likely to be less than 0.5% in 2020-30. Installed capacity of wind power in Europe, where it is most popular, was around 25,000 MW in 2003, almost doubling over the last two years. It is promoted by generous subsidies and tax credits.

Wind power is intermittent and correspondingly can not be relied on as a permanent electricity supply without adequate storage. This storage will make it uncompetitive. Wind power can still be competitive and useful in countries with proper wind regimes only as a limited source of electricity to augment existing electricity sources and save on use of fossil fuels. Its presence will add to energy security and energy independence in many countries, but only to a modest extent. Wind power can be utilized in the future for the production of (expensive) hydrogen.

Photo Voltaic (PV) cells have many useful small power applications. Most important it can provide electricity in small amounts to many households in the world that lacks it. But all this, as said earlier, will only make a small dent in the global energy scene.

The two principle instruments used to promote renewables are renewable energy feed-in tariffs (REFIT) or simple quotas. REFIT is a system where the price of renewable power is politically set in advance at a level high enough to attract sufficient investment and the producers' output is bought regardless of how much it may be valued on the market. The quota system sets output levels, or as a percentage of generation, or other measures (EEn Inf).

Much promise has been credited to hydrogen as a source of energy in the future. President George W Bush pledged in his 2003 State of the Union address that "the first car driven by a child born today could be powered by hydrogen and pollution-free". But is this realistic and justified! The most ambitious use of hydrogen is in a car powered by a fuel cell, a battery like device that turns hydrogen into electricity while emitting only heat and water vapor. Hydrogen can also be burned directly in engines much like those that run on gasoline, but the goal is fuel cells because they get twice as much work out of a pound of hydrogen. But where is this hydrogen coming from. The main source of hydrogen is natural gas, which is in short supply, cumbersome to convert and may have better uses. Waiting in the wings is coal, burned in old power plants around the world that are already the focus of a dispute over their emissions.

The long-term hope is to make hydrogen from emission-free "renewable" technologies, like windmills or solar cells. In fact, hydrogen may be an essential step to translate the energy of wind or sunlight into power to turn a car's wheels. But electricity from renewable technologies is costly. In the US, hydrogen is five times more expensive than gasoline when produced from wind and 17 times when produced from solar.

A likely source of hydrogen is from a machine called an electrolyzer, which is like a fuel cell in reverse. The fuel cell combines oxygen from the air with

hydrogen to produce an electric current, with water as a byproduct, while an electrolyzer runs an electric current through water to split the water molecule into its constituent hydrogen and oxygen atoms. The problem is that if the electricity came off the national power grid to run an electrolyzer, about half of it, on average, would be generated by coal. Another problem is emissions. According to the US DOE, an ordinary gasoline-powered car emits 374 grams of carbon dioxide per mile, or 1.6 kilometers, when driven, counting the energy used to make the gasoline and deliver it. The same car powered by a fuel cell would emit nothing, but if the energy required to make the hydrogen came from the electric grid, the emissions would be 436 grams per mile. Similarly, the car would not emit nitrogen oxides, a precursor of smog, but the power plant would.

Correspondingly an energy future, with hydrogen as its main fuel source, has to be viewed (at least now) with skepticism. It is not likely to come, if it comes, before the middle of this century.

During 2002, the EU commission proposed that there would be a 20% use of substitute fuels in road transport by the year 2020. The short term targets are to reach 2% by 2005 and 5.75% by 2010. The commission proposed that alcohol (ethanol) will be blended into petrol and that diesel oil will be partly replaced by vegetable oil derivatives. There are two approaches towards the solution: the use of pure vegetable oils; and biodiesel (transesteified vegetable oil or animal fat).

Bioenergy in the form of ethanol and similar fuels (from corn or other agricultural products) are likely to provide only a limited alternative to oil. Cultivation of crops for use as fuel requires substantial land that otherwise be available for food, or other uses. With present technologies ethanol is more expensive than gasoline. It also can require substantial inputs of fossil energy for production and conversion into fuels. The Brazilian experience of the last many years has mixed results. Most new cars in Brazil are now sold to burn a mixture of biofuels and 75% gasoline. Of course ethanol production does provide a measure of energy security but at a price.

Bioenergy in the from of ethanol and similar fuels (from corn and other agricultural products) are unlikely to provide a long term alternative to oil. Cultivation of crops for use as fuel requires substantial land that otherwise will be available for food. The result of the Brazilian experience of the last twenty years has been controversial. Brazil now sells biofuels at a cost equal to or below petrol. But in view of independent studies this could only be achieved through subsides (Baker Institute).

THE FUTURE OF CARBON EMISSIONS

The future of carbon emissions can now be predicted relatively without much difficulty, because the fundamentals are now almost known and are unlikely to change for the next 25 years. These fundamentals are not encouraging towards a carbon less future, they are:

(1) There is no foreseeable viable alternative to fossil fuels.
(2) The future of new and renewable energy is not bright. Too much talk, promises, conferences, etc., but very little real market achievement. Its contribution may increase gradually but will not change the structure of the global energy balance.
(3) Kyoto Protocol is not likely to be ratified in the foreseeable future. It is now seven years since the agreement, with no helpful signs for ratification. Even if ratified there are so much flexibility in the targets and mechanisms as to limit its effectiveness.
(4) Nuclear energy, which is carbon free, is still shunned by majority of nations.
(5) Technological progress in carbon containment, sequestration, storage, etc. is happening, but it will be many years before it will have a sizable effect on carbon emissions and reduced concentration in the atmosphere.
(6) Most of the growth in energy demand is going to be in DCs. These countries are mostly concerned with economic growth and least worried about global warming. Consequently they will continue with their relatively carbon intensive economic growth using their local sources (mostly low quality coal) with little consideration for emissions.

But equally there are few (but important) bright spots

(i) Energy efficiency (low intensity in energy use) is not only continuing but also improving. This is mostly happening in electricity generation. The world is gradually becoming more electrified with electricity utilization growth is at least 1.5 times that of total primary energy usage growth. New electricity generating facilities are increasingly of the CCGT type which has relatively high efficiency and low emissions per kWh (less than half) particularly when natural gas is utilized.
(ii) Natural gas utilization (which relatively a benign fuel) will continue to increase at a rate higher than total energy use. Natural gas demand is expected to grow at a rate at least 1.5% of primary energy growth (2.7% annually compared to 1.7% for energy). Natural gas growth rate will be twice that of coal. Trading in LNG is improving, so also prospect of gas to liquid, and in the future coal gasification.

(iii) There is global awareness about global warming, and carbon emissions. Even if Kyoto is not ratified, its message and mechanisms are not forgotten and will foster carbon restraint, particularly among OECD countries.

A time span of 20-25 years is relatively not lengthy in term of energy development. Correspondingly it is now possible to predict with reasonably accuracy the future of emissions which are going to influence global warming. I am not going to venture new predication from my own, but will mainly rely on US-EIA and the IEA figures.

But let us start with the emissions at end of 2003. They point out to the following:

Carbon emission (2003)	24 750 million metric tons
Growth of emissions (1990-2003)	18.3 %
Growth of emissions of US (1990-2003)	19 %

The future of carbon emissions may look as follows.

IEA Predictions

Year	CO_2 million tons	Growth % (annually)
1971	13 654	1.74 %
2003	24 700	1.78 %
2030	38 200	

US – DOE EIA Predictions

Year	CO_2 million tons	Growth % (annually)
1990	21 563	0.94 %
2001	23 900	1.9 %
2025	37 124	

The writing on the wall is clear. We are destined (at least in the medium-term till 2030) for relatively high growth in carbon emissions. Prospects for global warming are only warmer.

REFERENCES

ExxonMobil. "A Report on Energy Trends, Greenhouse Gas Emissions and Alternative Energy", 2004.

Gerholm, T R 1991. "Electricity in Sweden-Forecast to the year 2050", Vattenfal, Sweden.

IAEA. "Energy, Electricity and Nuclear Power Estimates for the Period up to 2020", Vienna.

IEA (WEIO), 2003. *World Energy Investment Outlook*, IEA, Paris.

Khatib, H. *Economic Evaluation of Projects in the Electricity Supply Industry*, 2003.

US Department of Energy (US DOE), *International Energy Outlook 2004*, (IEO 2004).

WEA. *World Energy Assessment*, UNDP, New York, 2000.

WEO. International Energy Agency. *World Energy Outlook 2002*, Paris, 2002.