Nuclear Energy and the Greenhouse Problem

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SUMMARY Last November - almost in parallel with the Hague Meeting on Climate Change - more than 1,500 of the world's top nuclear scientists and energy technologists met in Washington DC, at the Joint Conference of the American Nuclear Society, the European Nuclear Society, the Nuclear Energy Institute and the International Nuclear Energy Academy. Unlike the United Nations follow up to the Kyoto protocol, which ended in disarray, a note of high optimism and informed realism pervaded the nuclear conference which, among its multiple streams of subject material and papers by international experts, carried the two main themes of Long Term Globally Sustainable Energy Options and Nuclear Energy and the Greenhouse Problem.

This paper considers the immense contribution to Greenhouse gas emission minimisation made by nuclear energy in 1999. In that year the global electricity production by the world's 435 nuclear power stations was 2,398 TWh or 16% of total electricity generation or 5% of total primary energy production. The amount of avoided carbon dioxide emission because of the use of nuclear energy in 1999 was 2.4 billion tonnes. This is 10% of total emissions. Japan's 54 nuclear power stations alone save the equivalent of Australia's total Greenhouse emissions. The secret of this success is Australia's uranium fuel.

1. INTRODUCTION

Kyoto, the ancient capital of Japan, is an elegant city blending in a pristine environment with hills, streams, pine forests and manicured gardens and parklands. Here the buildings, shrines, rocks and paths exhibit the responsible environmental stewardship of human beings over many centuries. Light and air-conditioning for the modern International Convention Centre is obtained from an electricity grid supplied partly from a network of fifty-four nuclear power stations. The greenhouse gas emissions saved by the use of this network and the uranium fuel cycle is around 287,000,000 tonnes of carbon dioxide per annum. This is about the same as Australia's total emission.

Delegates from the developed countries attending Kyoto understood that behind the alarming growth of carbon dioxide in the atmosphere is the mechanism of population growth and energy usage in the developing countries. The United Nations anticipates that the present world population of 5.5 billion will rise to 8.5 billion by the year 2025. Of this 3 billion increase some 2.8 billion will be in developing countries which already account for 75% of the world's population. About this time it is estimated that China's greenhouse emission will be around four times greater than that of all industrialised countries together in 1990! It is likely that even with a modest growth in her economy, by the year 2000 China's annual demand on primary energy will be equivalent to 1.5 billion tonnes of standard coal and 1,400 billion kilowatt hours of electricity. Her present carbon dioxide emission per unit gross national product is around 6,000 tonnes per US dollar - one of the worst in the world.

A significant amount of the uranium fuel used in Japan comes from Australia. in fact, for every twenty-five tonnes of uranium exported from South Australian and Northern Territory mines, Japan averts around one million tonnes of carbon dioxide emission.

Australia is certainly not in the same league as China as global polluter. One wonders how a United Nations conference such as Kyoto can have any real impact on greenhouse emission and climate change without first involving and setting binding emission targets for the developing nations? Or how can another major polluter, the United States - consuming around 33% of the world's resources and producing some 24% of the world's carbon dioxide emission - exercise her massive eco-political lobby at such a conference without first settling her domestic industrial and environmental issues in Washington.

Unlike Japan, where 35% of the electrical energy now comes from nuclear power stations, Australia has never, ever, made any major changes in energy technology., Throughout her industrial history she has relied primarily on fossil fuels. Thirty years ago she rejected nuclear energy ostensibly on the basis of cost. This is ironic when we consider that today, especially if a "carbon tax" is to be imposed on fossil fuel users, nuclear energy in many parts of Australia will prove to be highly competitive. Even more

bizarre is the somewhat sinister attempt by some Australian State governments to saddle electricity consumers with subsidised high cost "renewable" energy sources. The promotion and advertising of such schemes by "sustainable energy development authorities" and segments of
the energy industry is so contrived as to make honest academic researchers blush with embarrassment. This form of cross subsidisation of national energy resources could drive Australian energy costs to such a level as to make Australia's floundering manufacturing industries completely non competitive on world markets.

2. THE GLOBAL ENERGY SCENARIO

Availability of air, water and energy are absolutely essential for human life. As far as energy is concerned the past evolution and projections up to 2050 made by the World Energy Council, indicate the following trends in energy consumption, taking 1960 as a reference.

Year	1960	1980	2000	2020	2050
Population	3 billion 1 (reference)	4.5 billion x 1.5	6 billion x 2	7.5 billion x 2.5	8-10 billion x 2.7 to 3
Total energy demand (heat, electricity and transport)	100% (≈3 Gtoe*)	210%	320% (≈ 10 Gtoe)	450%	600% (≈ 1 8 Gtoe)
Electricity only	100% (-2000 Twh**)	400%	700% (15,000 Twh)	1000%	2000% (42,000 TWh)

*Gtoe = one Gigatoe : the equivalent of one billion tonnes of oil

According to this realistic estimate, the demand for electricity will probably triple from now to 2050 for the following five reasons:

- the general increase in the world's population the increase in the fraction of the population living in cities (there are already 10 cities with over 20 million inhabitants)
- the improvement of general well-being: today some 2 billion people have no access to a commercial supply of energy
- the easiness to use, reliability, comfort and cleanliness of electrical energy as compared to other sources of energy
- the "explosive" increase in the demand for energy in the heavily populated developing countries.

From these figures it is clear that energy demand, especially the demand for electricity, will increase substantially in developing countries; and that all sources of energy will be called upon to meet that demand: fossil fuels, hydropower, nuclear power and renewable sources of energy such as biomass, wind, solar, etc.

In 1999 oil, coal and gas together supplied some 87% of the energy consumed in the world, hydropower 6.5% and nuclear power 5.5%. Although new gas fields are being discovered and the efficiency of extracting oil are increasing continuously, it is expected that these resources will begin to run out be 2050. Hence, other sources of energy including renewable energy (hydropower, solar, wind and biomass), and especially nuclear energy will have to play a major role.

A probable evolution of total energy supply is given on the following page, showing the important share of nuclear power.

3. COAL AND NUCLEAR COMPARED

Nuclear power does not produce $C0_2$ or other greenhouse gases, and also does not produce any $S0_2$, NOx or other gases which contribute to acid rain. These characteristics of nuclear power are especially important in comparison to coal fired generation of electricity which contributes 40% of all electricity generation in the world. Also part of the waste resulting from the burning of coal, namely the toxic metals such as arsenic, cadmium, lead, mercury, remains dangerous forever, contrary to the wastes of nuclear power generation.

Year	2000	2020	2050
Fossil fuel (oil, gas and coal)	86%	87%	70%
Renewables including hydropower	7.5%	6.5%	8%
Nuclear power	6.5%	6.5%	22%

Source: P.R.Bauquis (TOTAL-FINA-ELF), Revue de l'Energie, Sept. 1999.

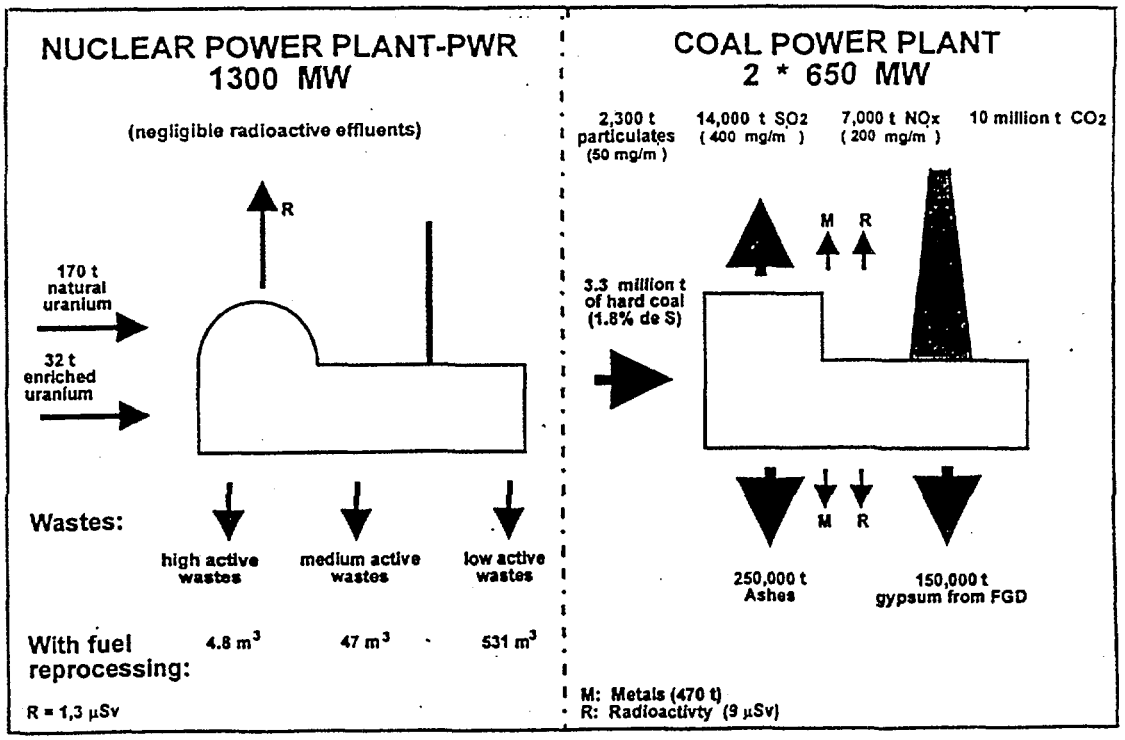

Figure 1 Annual fuel and waste disposal requirements of a 1,300 MW plant(Annual production: 10.000 GWh)

As an example (Figure 1), in comparison with a modern coal-fired power plant of the same size and with advanced abatement techniques, a 1300 MW(e) nuclear power plant eliminates annually emissions to the air of about: 2,300t on particulates; 10 million t of CO_2; 14,000t of SO_2, and 7,000t NOx the precise quantities being dependent on coal quality, power plant design, thermal efficiency, the effectiveness of the abatement systems and the operational performance of the plants. Table 1 gives an idea about the concentrations of toxic constituents in coal and quantities resulting annually from the operation of a coal power station similar to the one described in Figure 1. It must be emphasised that there are large differences between coals of different origins, and the data here refer to a "clean" coal.

It can be seen that a nuclear power plant can avoid the emission of some 10 million t CO_2 per year, the main greenhouse gas. Usually the opponents of nuclear power concede these facts but argue that nuclear power is such a small part of the world energy balance that it is insignificant to the big issue of climate change. This is hardly correct. Today, 16% of the world electricity is generated using nuclear power. If this electricity were to have been generated using coal, it would have resulted in abut 2.4 billion t of CO_2 annually. It means that nuclear power is already avoiding 10% of present CO2 emissions by all sources and more than 35% by the power sector (see Conclusions). Nuclear power is a proven, safe and reliable source of electricity. It is, therefore, vital that it receives the credit it deserves for this contribution to the reduction of greenhouse gas emissions.

Table 1 Toxic constituents in coal and annual emissions from a coal power plant

Constituent	content in coal (g/t)	emissions (t/year)
Arsenic	30	99
Cadmium	1	3
Copper	12	40
Lead	12	40
Mercury	0.1	0.5
Radium	2.7x10-7	-
Thorium	1.7	6
Uranium	0.78	3
Zinc	86	284
Total	144	475

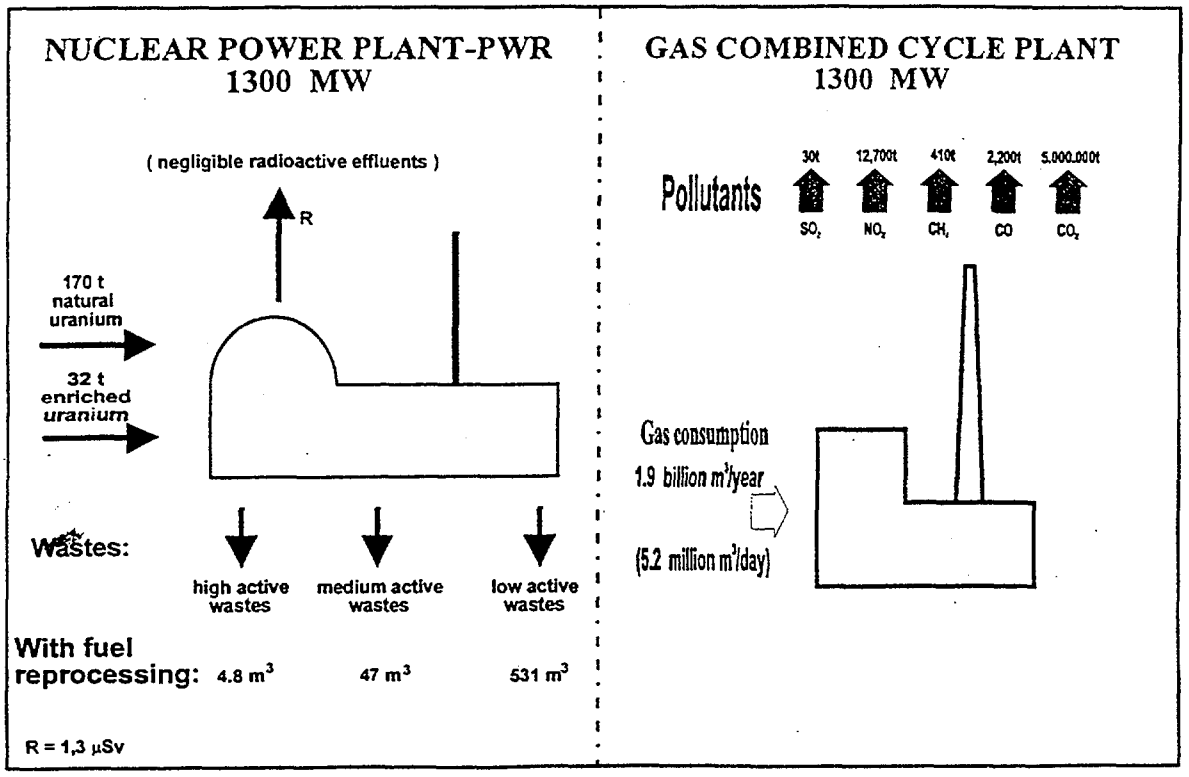

Figure 2. Annual fuel and waste disposal requirements of a 1,300 MW plant

4. GAS PLANT AND NUCLEAR COMPARED

It is often said that nuclear power should not be compared with coal power plants, responsible for 40% of the world electricity production, from the environmental point of view. It is claimed that a fair comparison should be made with natural gas, considered to be, by definition, a "clean" source of electricity production and the fuel of the future. Not discussing the availability of gas and the usual assumption made by decision makers that the price of gas will stay low for the next 30 years, the lifetime of a power plant, some points will be put forward from the environmental point of view which in our view are being disregarded when stating gas as a "clean" technology. To start with Figure 2 compares a nuclear power plant with a gas combined cycle power plant as far as generation is concerned only.

Table 2 on the following page summarises some of the more important consequences of switching from hydrocarbon to nuclear fuels.

Table 2. CO_2 Emissions in the World

Emissions by the combustion of fossil fuels: 24 billion tons of CO_2 annually
World electricity production by nuclear power: 2.398 TWh in 1999 16% of the total electricity generation 5%of total primary energy production
Amount of avoided CO_2 emissions due to the use of nuclear power in 1999 2.4 billion tons of CO_2 (10 % of total CO_2 emissions)
Recommendation from the TORONTO CONFERENCE (1988): Cut total present annual emissions by 20% (4.5 billion tons of CO_2) up to 2005
Power Sector: CO_2 Emissions: 6.5 billion tons of CO_2 (27% of total emissions) Avoided emissions due to the use of nuclear power: 35% of total emissions of the power sector

Table 3 gives a detailed analysis of the Carbon Dioxide emissions averted by the thirty-two nations within the global community which already use nuclear energy.

Finally, the fuel, land and transport requirements of typical coal and nuclear electricity generating plant are compared in Table 4..

As it can be seen from the figure above the combustion of gas emits several air pollutants such as S02, NOx CH4,CO and C02. Particularly the emissions of nitrogen oxides, one of the responsible for acid deposition, and carbon dioxide (C02), the main greenhouse gas, are substantial. If one considers the full-energy-chain, there are emissions of methane (CH4) during the process of extraction and transportation of gas. As methane to a much stronger greenhouse gas than C02, transforming the amount of methane in C02 equivalent, the emissions of greenhouse gases from the use of gas in electricity production might be of the same order as those of the coal cycle. From these considerations it can be said that use of gas cannot be claimed as the solution to the climate change problem. There are many objections to considering gas as a "clean" fuel.

5. CONCLUSIONS

The desirable environmental impacts of nuclear energy in respect of the greenhouse gas problem is so great that it is difficult to envisage the eventual binding observance of the Kyoto Protocol without a global acceptance of nuclear technology in national energy policies.

6. ACKNOWLEDGEMENTS

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Table 3. Carbon dioxide emissions avoided by nuclear energy

Country	Nuclear electricity generation 2000		Reactors operating Sept. 2001		Carbon dioxide emissions avoided 2000
	%	TWh	No.	MWe	million tonnes
Argentina	7.3	5.7	2	935	6
Armenia	33	1.8	1	376	2
Belgium	57	45	7	5728	45
Brazil	1.5	5.6	2	1855	6
Bulgaria	45	18	6	3538	18
Canada	12	69	14	9998	69
China	1.2	16	3	2167	16
Czech Republic	19	13.6	5	2560	14
Finland	32	21	4	2656	21
France	76	395	59	63203	395
Germany	31	160	19	21141	160
Hungary	42	15	4	1755	15
India	3.1	14	14	2548	14
Japan	34	305	54	44301	305
Korea RO (South)	41	104	16	12970	104
Lithuania	74	8.4	2	2370	8
Mexico	3.9	7.9	2	1364	8
Netherlands	4	3.7	1	452	4
Pakistan	1.1	1.1	2	425	1
Romania	5.1	5.1	1	655	5
Russia	15	120	30	20793	120
Slovakia	53	16	6	2472	16
Slovenia	37	4.5	1	679	5
South Africa	6.7	13	2	1842	13
Spain	28	59	9	7345	59
Sweden	39	55	11	9460	55
Switzerland	36	24	5	3170	24
Taiwan	24	37	6	4884	37
Ukraine	47	72	13	11195	72
United Kingdom	22	78	78	12528	78
USA	20	754	104	98060	754
WORLD	16	2447	438	353,425	2449

Sources: the nuclear power reactor data files of ANSTO, based on information to I Sept 2001.
IAEA - for electricity production
Basis: 1 TWh would require 409,000 tonnes black coal @ 67% carbon.
World carbon dioxide emissions from electricity generation are about 7500 million tonnes per year (5300 Mt from coal). Electricity contributes about one third of the world CO_2 emissions.

Table 4. 1300 MW(e) power plants with annual production of 10,000 GWh

	Coal	Nuclear
Installed capacity Fuel Fuel annual consumption	2 x 650 MW(e) hard coal 3.3 million tons	1300 MW(e) enriched uranium 32 t enriched U (170 t natural U)
Land use for plant site, mining and waste disposal	415 ha	60 ha
Area requirements for fuel storage	25 ha (2 months reserve)	few ha only
Fuel transport requirements	82.500 wagons of 40 t each every year'	5 lorries each year
$C0_2$ emissions	10,000,000 t $C0_2$/year	0
$S0_2$ emissions W/FGD	14,000 t SO_2/year	0
NOx emissions w/denitrification	7,000 t NOx/year	0
particulates emissions w/control	2,300 t/year	0
Wastes	250,000 t ashes 140,000 t fly ashes 85,000 t sulphur 150,000 t gypsum	A cube of 1.5 m side with high radioactive wastes