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A REVIEW OF NUCLEAR POWER IN CHINA

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ABSTRACT

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Whilst nuclear power does not seem to have the support of public opinion in many parts of the world China is forging ahead with its ambitious nuclear programme. Some might argue that this is to support their weapons programme but that clearly is not the case and is undoubtedly to provide a stable source of energy for the generation of electricity but also for alternative peaceful uses.

This paper covers the history of nuclear power in China over more than thirty years and addresses what impact, if any, their policy of continued expansion of nuclear power will have on the rest of the world. The different reactor types installed in China is reviewed, the infrastructure and the overall strategy is surveyed.

1. INTRODUCTION

1.1 Energy Usage

Energy usage varies from country to country throughout the world. Some countries are big consumers of energy whilst others are not. Industrialised and in general 'developed' countries are big consumers of energy whilst under developed countries consume much less energy. A reasonable measure by which to compare different countries is the per capita energy consumption. This value, however, is not an indicator of individual wealth or 'home comforts' since it based on total national energy consumption divided by the population of the country. By this measure there are numerous countries which consume more energy per capita than for example the United States of America. Some of these are given in W per capita below:

• Iceland	22,477
• Trinidad / Tobago	21,187
• Qatar	17,041
• Kuwait	16,248
• Luxembourg	11,107
• Brunei Darussalam	11061
• UAR	11,012
• Bahrain	10,323
• Canada	_9,825
• Oman	_9,569
• USA	_9,538
• Saudi Arabia	_8,212
• UK	_4,333
• China	_2,405
• Bangladesh	_,278
• Eritrea	_,189

The above indicates that some small Arab states with a small population are relatively large consumers of energy whereas China which consumes a large percentage of the world's energy has an enormous population and therefore the per capita figure is relatively small.

1.2 Per Capita Domestic Energy Consumption

Whilst energy in its different forms is indispensable to the quality of life in Western society it is not necessarily a feature of daily life in other parts of the world. In parts of Africa and Asia, life for millions of people has not changed substantially from what it was 2,000 years (and more) ago. For the fortunate few the only labour saving 'devices' they have are pack animals such as donkeys.

A comparison of per capita domestic energy consumption for six selected countries is given by a Cambridge study group and the results are listed in Appendix 1. It shows that domestic consumption of energy per capita in the USA is almost three times the world average and almost four times that of China.

In the study the authors state that:

"If a billion people - e.g. in developing China and India – adopt Western lifestyles, an extra 500MToE / per year will be consumed"

"Using existing coal, oil, electricity and gas sources this corresponds to 1.43 billion extra tonnes carbon dioxide released – just from the domestic sector!"

"MUST tackle domestic energy issues before power hungry technology and inefficient building and heating become available and are implemented worldwide."

The author does not agree with the implications of these statements since the reduction of world poverty must be the first priority before all else, rather than the reduction of carbon emissions. This means that energy must be widely available and must be affordable to the poorest members of society regardless of climate change.

Many of the world's poorest people live in makeshift habitation and it will not be feasible to provide them all with efficient buildings for the foreseeable future. They do, however, require energy as an urgent necessity and a first step to rising out of povertyⁱ.

1.3 Carbon Emissions, Climate Change & Energy

China has been criticised on numerous occasions for the amount of carbon emissions from its coal fired power stations. China has shown that it is sensitive to this criticism but cannot afford at the present time to slow down its production of coal fired power stations since this will have an adverse effect on its industrial and economic growth.

"The Chinese Government made a commitment in 2009 for the emission reduction target:

- Non fossil energy to take up of 15% total energy consumptions by 2020*
- By 2020, CO₂ emission per GDP unit to decrease to 40%-45% of that of 2005"ⁱⁱ*

Despite the fact that approximately 83% of its electrical energy currently comes from hydrocarbons, China has embarked on an aggressive policy to utilise other forms of energy. It is now the world's number one producer of electricity from wind energy. It has also, with the opening of the Three Gorges Scheme, overtaken Brazil as the world's biggest producer of hydro-electricity. In fact, China has an extensive programme to promote all kinds of renewable energy and to reduce carbon emissions also by closing down older inefficient coal fired power stations.

Despite many arguments to the contrary, however, a large industrialised country such as China requires a 'balanced mix' of energy and cannot base its energy policy solely on 'renewables'¹. The Chinese Government has sensibly made nuclear energy² the 'backbone' of its

¹ Since these are unreliable, inefficient, have a low capacity factor and in general have other failings.

² Which is carbon free

energy policy so that it will have a reliable source of energy for the next thousand years or for the foreseeable future, however long that may last.

2. ELECTRICITY FROM NUCLEAR ENERGY

2.1 Historical – Qinshan & Daya Bay

China has been interested in nuclear energy for many years but commercial nuclear energy only really 'took off' in the 1980s along two different paths. One was in the midlands close to Shanghai and driven by the China National Nuclear Corporation (CNNC). The other was in the south and driven by the China Guangdong Nuclear Power Group (CGNPC).

A 'home grown' single loop water cooled 300MW pressurised reactor was developed and designed by Shanghai Nuclear Engineering Design and Research Institute (SNERDI). The reactor was built at Qinshan in Zhejiang Province, with some imported parts and is operated by the China National Nuclear Corporation (CNNC).

"Construction work spanned 6.5 years from March 1985, with first grid connection in December 1991."^v

"Qinshan Phase II units 1 & 2 are locally designed and constructed 2-loop PWR reactors, scaled up from Qinshan I, and designated CNP³-600. local content was 55%. Unit 1 started up at the end of 2001 and entered commercial operation in April 2002. Unit 2 started up in March 2004, with commercial operation in May 2004. Units 3&4 are similar, with a local content of 77%. After 53 months construction, unit 3 was grid connected on 1 August 2010, and entered commercial operation in April 2012. CNNC claims that Qinshan phase II 'is the first independently-designed, built and operated large commercial nuclear power station in China' "

For CNNC the logical next step was to follow up the two loop units with a 3-loop CNP-1000 unit, however, this is unlikely to take place as the Chinese Government made a major policy change (following the problems at Fukushima Daiichi in Japan in 2011) in favour of the Westinghouse AP1000 design which has more 'passive' safety features.

The second development took place at Daya Bay in Guangdong Province on the coast opposite Hong Kong. Framatome and the Consortium of French companies under the name 'Framateg' were eager to continue 'the momentum' achieved by the completion of their first power station turnkey contract at Koeberg in South Africa⁴. The EdF CP1 and CP2 reactors were essentially 3-loop 900+ MWe PWRs of Westinghouse design and built under licence in France by Framatome. The same unit in China was designated M310 by Framatome.

"Electricite de France (EDF) managed construction, starting August 1987, with the participation of Chinese engineers. Commercial operation of the two Daya Bay units was in February and May 1994. The plant produces about 13 billion

³ CNP = China Nuclear P(PWR)

⁴ They had an order from Iran but that was aborted after the Iranian coup

kWh per year, with 70% transmitted to Hong Kong and 30% to Guangdong^v.”

In addition two more units of French design were built at adjacent Ling Ao also in Guangdong Province.

“The Ling Ao phase 1 reactors are virtually replicas of adjacent Daya Bay units. Construction started in May 1997 and Ling Ao 1 started up in February 2002 entering commercial operation in May. Ling Ao 2 was connected to the grid about September 2002 and entered commercial operation in January 2003. The two Ling Ao reactors use French M310 technology supported by Framatome (now Areva) but with 30% localisation. They are reported to have cost \$1800 per kilowatt.”

The Daya Bay and Ling Ao reactors are operated by China Guangdong Nuclear Power Group through their subsidiary Daya Bay Nuclear Power Operations & Management Co (DNMC) – established in March 2003 by the joint investment of Guangdong Nuclear Power Joint Venture co. Ltd (GNPJVC) and Ling Ao Nuclear Power Co., Ltd (LANPC).^{vi}

2.2 Current Status in 2013

In the 28 years since the start of construction of Qinshan phase 1, China has commissioned 17 operating reactors – an average of more than 1.6 reactors each year providing a total of almost 14 GWe. Apart from the four French designed reactors in Guangdong Province there are four other foreign designed reactors; two Canadian PHWR heavy water 665 MWe reactors at Qinshan phase III; and two Russian VVER 1000 MWe (PWR) reactors at Tianwan 1 & 2 in Jiangsu Province. The remaining nine reactors are all Chinese designed and built although many imported parts have been used in their construction.

A complete list of current operating reactors can be found from various internet sources.

All of the reactors are pressurised water reactors with the exception of the China Experimental Fast Reactor (CEFR) which is grid connected and producing 20MWe.

2.3 Short Term Future

The short term future may be regarded as the next seven years up to 2020 – about the length of time required to plan and build a new reactor.

28 new reactors are already under construction: these include four - Westinghouse designed Advanced Pressurised Water Reactors (AP1000) of 1,250 MWe each (1.25 GWe); two – French designed European Pressurised Reactors (EPR) of 1,770 MWe each; one of two Russian designed Vodo-Vodyanoi Energetichesky Reactors (VVER-1000) of 1,060 MWe each; eighteen Chinese designed China Pressurised Reactors (CPR-1000) of 1,080 MWe each; two Chinese designed China Pressurised Reactors (CPR-600) of 650 MWe each; one experimental High Temperature Pebble Bed Reactor (HTR-PM) of 210 MWe being developed through the University of Tsinghua.

Work on the world's first generation III AP1000 reactor at Sanmen in Zhejiang Province is on schedule and it is anticipated that it will be started up in 2014^{vii}.

Further reactors are planned for completion by 2020. In 2007 the State Council issued “National Power Middle and Long Term Development Plan” (2005-2020) of 40 GWe in operation and 18 GW under construction i.e an increase of 44 GW from the reactors currently operating, an increase of 314%. This target could be achieved before 2020 and a revised target of 80 GW was proposed although this is unlikely to be met due to delays arising from Fukushima safety reviews.

2.4 Long Term Future

Once the targets for nuclear supplied electricity have been reached by 2020 China anticipates almost quadrupling supply to 200 GW by 2030 and then doubling again to 400 GW by 2050.

China is basing its future on the pressurised water reactor originally invented by Westinghouse and upgraded to Generation III by the AP1000 design. The Chinese authorities signed an agreement with Westinghouse for 'a major technology transfer agreement' and most, if not all the future reactors will be built with Chinese expertise. It is likely that the CPR-1000 design will be abandoned in favour of the AP1000 which in China will become the CAP1000. An upgrade will be produced in the future to the CAP1400 – a 1.4 GWe reactor.

“The reactors are built from modules fabricated adjacent to each site. The timeline is 50 months from first concrete to fuel loading, then six months to grid connection for the first four units, with this expected to reduce significantly for the following units. The cost of the first four is expected to be less than \$2,000/kW, with the reducing to \$1,600 for further units. In October 2009, SNPTC and CNNC signed an agreement to co-develop and refine the AP1000 design and this position strengthened following the Fukushima accident.”^{viii}

SNPTC – State Nuclear Power Technology Corporation

One of the problems China suffers from is fuel supplies and whilst there is currently a worldwide abundance of uranium from countries such as Australia, Canada, Namibia, Niger, Kazakhstan etc., and China is also sourcing its own local supplies, future supplies may be a problem. Accordingly, China has embarked on a policy of re-processing spent reactor fuel⁵. In addition it is embarking on a programme of fast reactor technology so that natural uranium may be used more efficiently⁶. An experimental 20MWe CEFR has already been commissioned. An agreement has been signed with Russia for a reactor of the type BN-800^{ix}, an 880MWe fast reactor currently being built by OKBM Afrikantov at Beloyarsk in Siberia. This is an upgrade to the successful

⁵ Over 95% of spent fuel is re-usable.

⁶ Natural uranium contains only 0.7% fissionable U235 and 99.3% U238 but which can be converted in a fast reactor to Pu239 which is fissionable thereby extending the availability of uranium fuel by almost 1000%.

BN-600 which has been in commercial operation since 1980.

Beyond the fast breeder technology lies the possibility of fusion power which is not expected before about 2050. China is involved in current efforts to develop fusion technology such as the ITER project.

3. IMPORTANT CONSIDERATIONS

3.1 Safety

The Tohoku Earthquake and tsunami which occurred in western Japan on 11 March 2011 reportedly caused 15,883 deaths, 6,143 injured and 2,681 people missing. Despite these facts the most publicised event is the 'accident' at Fukushima Daiichi Nuclear Power Station, yet no one died from excessive radiation exposure and the levels of radiation that were experienced by the public were extremely low. Nevertheless, the world reaction was to:

- close nuclear power stations in Germany
- abandoned the nuclear option in Italy and other countries
- postpone or delay nuclear projects in almost every country in the world.

In China all construction work and new projects were halted whilst the inspectorate conducted a thorough safety review of existing and future power plants. Various recommendations were made for implementation but the main outcome apart from the delay to the programme was to opt for the Westinghouse AP1000 as the best and safest option. Certain shortcomings were highlighted from Fukushima, mainly the importance of maintaining cooling to the reactor and the continued availability of standby power in an emergency.

China has adopted all the recommendations of the International Atomic Energy Agency (IAEA) and is a full participant in all safety forums.

Notwithstanding Chernobyl, nuclear power is one of the safest industries. Although many people believe otherwise it has an enviable safety record and due to the efforts of INPO,⁷ WANO⁸ and others is improving every year. The civil nuclear industry can claim more than 14,000 years of operation in 32 countries with only one accident involving fatalities [6].

Some information on safety is given in Appendix 3

3.2 Performance

The performance of the operating plants is good with an average load factor of 90%. The capacity factor is also well above 90% which compares well with some of the US plants (Calvert Cliffs 99%). According to Wang Bo^{xii}:

- Good safe record, no class (INES) and above events

- Radiological release, far below the statutory limits
- Good performance with average load factor of (0% recent years)
- Good ranking, H2010 average assessed score of 94 in 100 by WANO criteria
- Performance continuously improving

The real problem may come in training sufficient personnel to meet the demands of the ambitious programme.

There is an agreement for operators to be trained by Duke Power in the USA.

3.3 Self Sufficiency

Since the early days of the French reactors at Daya Bay, China has built up a completely new industry and is virtually self-sufficient in everything as follows:

Reactor Pressure Vessels -manufactured by:

First Heavy
Dongfang Electric
Shanghai Electric

Steam Generators – manufactured by:

Harbin Electric
Dongfang Electric
Shanghai Electric

Internals – manufactured by:

Harbin Electric
Dongfang Electric
Shanghai Electric

Control Rod Drive Mechanism by:

Harbin Electric
Dongfang Electric
Shanghai Electric

Primary Pump by:

Harbin Electric
Dongfang Electric
Shanghai Electric

Turbo-Alternator by

Harbin Electric
Dongfang Electric
Shanghai Electric

Local supply is now more than 80% on all new plants.

Fuel Supplies – this was mentioned briefly above. China has various agreements in place for fuel supplies and in the long term is adopting the closed fuel cycle by reprocessing spent fuel and relying on fast breeder reactors to increase fissionable material. China is also researching the thorium cycle.

3.4 Health

With 80% of its electricity being produced by coal it is well known that many cities in China suffer from air pollution, which affects the health of the population

A 1988 World Bank report^{xiii} it was stated that there were 750,000 premature deaths in China from air pollution. In addition in 2011 there were approximately 2,000 deaths

⁷ Institute of Nuclear Power Operators

⁸ World Association of Nuclear Operators

from coal mining. This figure has reduced significantly from almost 6,000 deaths in the year 2000 primarily due to Government efforts to improve safety and to close small dangerous mines.

In comparison, nuclear power stations provide a clean healthy working environment. In reviews of workers at nuclear power stations in different parts of the world, the workers were found to have as good if not better health than the rest of the population.

Nuclear power stations are environmentally friendly and support wildlife.

3.6 Climate change

China's current emphasis on nuclear and renewable sources of energy must be applauded by all those who warn of the dangers of climate change.

Whatever the true dangers of climate change the switch away from coal technology can only be good in the long term.

3.7 Environmental

Every method of electricity production has an adverse effect on the natural environment.

The erection of any large structure with concrete foundations and access roads will have an impact on the environment and biodiversity. If there are mining activities, the use of chemicals for extraction, the rejection of unwanted material such as rock and tailings or the production of waste, the impact will be enhanced. Also the emission of gaseous contaminants or discharge of liquid effluents will enhance the effect.

The fuel most damaging to the environment and the one which is most common is coal yet despite the detrimental impact more CFPs are being built every year and at a greater rate (in GW) than previously. Coal is cheap, convenient and plentiful⁹. It supports the coal mining industry which provides jobs and capital from exports. Most of the present day growth is in Asia, particularly China. The expansion of industry in these countries and the drive for self improvement is so great that it has gathered a momentum that is almost unstoppable^{10[xiii]}.

There have been advances in technology to make CFPs cleaner burning by the inclusion of scrubbers, precipitators (ESP) and flue gas desulphurization (FSD) hopefully, in the fullness of time these improvements will prevail (including CCS).

Other hydrocarbons such as oil and natural gas have similar problems to coal. Oil has caused some of the worst ecological disasters in history¹¹. Natural gas emits

the least carbon but then methane is a more potent GHG than carbon dioxide and inevitable leaks may make up for the lower carbon emissions.

NPPs have problems. Damage is caused to the environment by uranium (U) mining¹², it is however, much safer than coal mining and modern methods use leaching to extract the U at a low risk to the miners. There is possibly a controlled risk through the use of sulphuric acid and other chemicals.

When operated correctly and controlled according to approved procedures the effect of NPPs on the environment is small¹³. The emotive issue of radioactive waste is dealt with separately.

3.8 Nuclear Waste

Nuclear Power Plants do produce nuclear waste; however, one should consider the following:

97% of spent fuel need not be regarded as waste and can be recycled (like glass, paper, plastics etc) to be used again since it still contains 95-96% reusable U and about 1-2% Pu both of which are valuable fuels and can be converted into MOX¹⁴ fuel. Fission products also contain valuable elements such as platinum group metals.

Much of the problem of managing nuclear waste is a political one and it seems if the 'will' exists the 'way' can be found. The problem is principally one of cost and persuading local communities of the benefits. It's a question of economic priorities. The UK has a low level repository at Drigg in Cumbria but all other wastes which aren't reprocessed are stored at the various licensed sites. This situation has existed for more than 50 years and it must be assumed that the government does not consider a central repository a high enough priority. In the USA, the Yucca Mountain project debate has been ongoing for 23 years, in the meantime a number of plants have been satisfactorily decommissioned and the wastes removed.^[xiv]

All existing NPPs have funds set aside for decontamination & decommissioning and it is costed into all new NPPs.

NPPs are monitored and subjected to periodic inspection by their appropriate regulator and environmental protection agency to ensure that groundwater and other criteria comply with the stringent conditions of their operating licence.

Interestingly, CFPs emit more radioactive material (U & Th) into the environment than NPPs which is unregulated and a possible source for proliferation.^[xv]

¹¹ From drilling and transportation

¹² in reality is no worse than other kinds of mining and uranium is often a by product of other kinds of mining.

¹³ Other industrial activities often have a greater environmental impact.

¹⁴ Mixed oxide fuel

⁹ in some parts of the world

¹⁰ China is reputed to be building 2 coal fired plants each week and is expected to build more than 500 plants before the end of the decade.^[12]

The waste dumps from gold mines in South Africa have been bought by commercial enterprises¹⁵ to extract the valuable U contained therein. Perhaps in the future waste dumps at CFPs will be sought for the minerals they contain.

3.9 Social Factors

Sixty years ago people accepted smoke and smog as part of everyday life. There used to be a saying in Lancashire, England "Where there's muck there's money" but many people suffered from respiratory diseases such as bronchitis and asthma. Much of the smoke was from domestic fires burning coal for heating but there was also a considerable amount of atmospheric pollution from industry and power stations. The Clean Air Act was enacted in Britain in 1956 and led to the establishment of smoke free zones and the use of smokeless fuels.

Despite all the problems with CFPs, coal creates jobs and there are many areas in the UK where coal mining was a way of life which are now downbeat with mass unemployment. To-day there are many social problems which never existed in the past.

In contrast to coal, WPPs create very few jobs and tend to benefit the landowner and the power company the most as the generous payments they receive are covered by tax added to energy bills¹⁶ - robbing the poor to give to the rich.

Many pensioners and poor people indirectly subscribe through taxes to government grants & incentives for private windmills which benefit the affluent, something denied poorer people who can only afford to buy electricity through coin operated meters.

The majority of people who live near NPPs want more of them because they bring jobs and other benefits to the community whereas WPPs have the opposite effect – the people who live near to them dislike them the most.

3.10 Economics

In 2004 the British Royal Academy of Engineering published report "*The Cost of Generating Electricity*"^[xvi]. Their stated aim, "*to provide decision makers with simple soundly based, indicators of cost performance for a range of different generation technologies and fuels.*" The study was confined to various types of plant appropriate to the UK (Appendix 4)

The report compared the cost (in pence per kWh) of generating electricity from various primary sources and concluded that NPPs are competitive and cheaper than WPPs. They estimated that a reasonable figure for nuclear including capital costs and decommissioning is about 2.3 p/kWh whereas onshore wind power was more than double at 5.4 p/kWh (3.7 without back up power) and

offshore wind was almost three times the cost of nuclear at 7.2 p/kWh (5.5 without back up).

It is possible that new WPPs have improved since the report was published in 2004 but it is expected that the basic differences still apply.

EIA's "*Annual Energy Outlook 2010*" - "*2016 Levelized cost of New Generation Resources*" predicts electricity from WPPs to be more expensive than nuclear - yet less reliable. Additional costs are required for back up power or network modification.

WPPs require taxpayer subsidies so the consumer is not only paying higher taxes for the dubious 'benefit' of having wind power but is also paying higher costs for electricity. National networks are compelled by government to give priority to wind power even if it is not the best option. WPP companies in Britain are paid even if they don't supply electricity.^[xvii]

Denmark has the most WPPs per capita in Europe and the most expensive electricity. France has the most NPPs and the cheapest (pre tax) electricity.^[xviii]

3.11 Sustainability

The following Oxford English Dictionary definitions apply:

- *Sustain* –keep going over time or continuously
- *Sustainable* – (of industry, development or agriculture) without depletion of natural resources

Nothing lasts forever. Even the Sun is predicted to die in about 5 billion years. To be meaningful sustainability needs to be relevant to a period such as a 50 or 100 years - although most plans only extend 5 or 10 years to have any degree of certainty.

With the possible exception of oil the Earth's fuel reserves will last at least another 50 to 100 years including future increases.

All methods of generating electricity use minerals taken from the Earth and all involve some kind of manufacturing process most of which presently emit GHGs. Any specific resource will in time be depleted. No method is completely sustainable.

Fossil fuels emit GHGs whilst generating electricity, but nuclear and renewables are only likely to emit GHGs during construction and manufacturing of the generating equipment. Transport and maintenance may also emit GHGs. Fossil fuels are being used faster than the Earth can produce and are unsustainable.

The author believes that WPPs are not as sustainable as NPPs:

- WPPs deplete Earth's land resources unsustainably
- WPPs require subsidies, unsustainable - uneconomic

¹⁵ e.g. Uranium One

¹⁶ In the UK 11% is added to utility bills to pay for WPPs.

- WPPs cannot keep going over time or continuously
- WPPs not self sustaining require backup
- WPPs require new transmission networks more land, more structures and more mineral resources.
- WPPs damage the ecology and wildlife
- WPPs do not sustain the local community

NPPs are more sustainable than WPPs as follows:

- NPPs minimise land use & can re-use existing sites.
- NPPs are self funding.
- NPPs can run on recycled fuel.
- NPPs can run continuously for extended periods
- NPPs need no back up power
- NPPs use existing transmission networks
- NPPs are friendly to wildlife and the environment
- NPPs provide jobs to sustain the local community

To meet world demand with EPRs would require less than 2000 of which 440 reactors are already operating (not EPRs).

EU *Strategic Energy Technology Plan* (SET)^[xix] incorporates *Sustainable Nuclear Energy Technology Platform* (SNETP)^[xx] to demonstrate the long term sustainability of nuclear energy. See Appendices 5 & 6.

CONCLUSION

China is paving the way for a renaissance of nuclear energy throughout the world.

It is not only cleaning up its environment, although this will take at least a hundred years but creating a new nuclear industry and a world revival of nuclear engineering, research and manufacturing which will have repercussions in many countries throughout the world.

Scientific Implications

There are many potential scientific advances which are possible in the future in electricity generation techniques such as more efficient wind turbines, improved solar cells, wind and wave technology, carbon capture techniques and new reactor designs which can contribute greatly to electricity supplies of the future. These must, however, be practical proven technologies before large sums of money are spent responding to fanciful ideas and 'knee jerk' reactions. One hopes that the free market culture of the USA will prevail in highlighting the way forward but leadership at the present time seems to belong to China which doesn't seem to care what policy is adopted as long as it produces the desired results. Whether the choice is fossil fuel, renewables or nuclear China seems to be in a 'learning phase' eager to embrace the latest global technology from whatever source.

Social Implications

Hopefully everyone living on Earth should have the benefits that electricity brings as well as clean air, clean water and a healthy environment. The fact that we used to live with smog, dirty rivers from chemical and

agricultural pollution, contamination of land and other undesirable practices need not persist in the future. There are choices to be made - is electricity the first priority or a healthy living? A healthy society also needs the ability to enjoy and find inspiration and freedom in the unspoilt open countryside and sea.

Wildlife and the Environment

There are many examples of 'environmentally friendly' NPPs. These include Sizewell B, UK, which is adjacent to the Minesmere Bird Sanctuary; Koeberg near Cape Town in South Africa which boasts its own game reserve; San Onofre in California which is adjacent to a beach used by surfers and is a popular recreational area; Susquehanna which has a Riverlands nature reserve; Calvert Cliffs which has a policy of land, forest management and wildlife protection; North Anna which is on an artificial lake built to provide the station's cooling and which has spawned a popular week end resort for water sports.

There are many others such as Hinkley Point, UK which supports natural habitats on the river Severn. At Chernobyl wildlife (animals and plants) flourished once the people had left.

Wind turbines kill birds and seals. No attempt is made to screen the 'propeller' blades as would be required by health and safety law for any other industrial installation.

Acceptance by Local and Wider Community

There is often a divergence of opinion between the local and wider community. For instance locals hate wind farms, 'out of towners' love them; locals love nukes, 'out of towners' hate them. Opinions are often formed from the media, 'big money' companies, manufacturers and 'armchair environmentalists'. The silent majority seem to be subjected to 'brainwashing' by a very vociferous and militant 'green' minority.

The Nuclear Option

The decade in which President Eisenhower announced his "Atoms for Peace" programme has sometimes been described as the 'The Atomic Golden Age'. It is likely that in future people will recognise the 1950s not as the pinnacle but as our first faltering steps that were only just the beginning.

In the United States the power companies have managed, against restrictions and determined efforts by nuclear protesters who are not interested in the wellbeing of the majority but only their own prejudicial and misguided ideas to hamper and block every move, to increase the output of NPPs without building any new plant. These operating plants have an enviable record of reliable service which improves year by year and is constantly breaking new records for reliability and performance.

Undoubtedly some of this criticism has had a beneficial effect, especially after TMI, and instilled a safety culture

and techniques that have served as an example to other industries. The continued adverse attitudes, however, are undeserved and often grossly exaggerated with misinformation, fantasy and lies.

In Finland, after much deliberation and extensive research a group of industrialists impartially decided that the best and most economical form of power was nuclear. They accordingly placed a contract with Areva for the first evolutionary 1600MW EPR. It is not unusual for the first of any large to have 'teething' problems. The plant is more than 80% complete and is on schedule for completion at the end of 2010 or beginning 2011.

Way Ahead for the Future.

Worldwide, CFPs will continue to operate, and be built, for many years to come probably for at least the next decade and those plants will be operating until 2070 if not beyond. Efforts to curb GHG emissions are commendable and must continue but as has been the case in Germany may not always have the desired effect. Communities desperate for electricity to improve their lives and power their industries will not see GHG suppression as a priority but if they could be persuaded that technologies other than coal offer a realistic, affordable and economic alternative there is a possibility that they could adopt a different approach. They are also likely to heed the message if it is serious and credible- not one that is based on myths.

"Catchphrases won't curb energy problems - A good energy strategy doesn't fit in a slogan" [xxi]

Climate Change

There appear to be real doubts as to the likely effects of climate change. We have no proof that some of the scenarios of global warming will come to pass or that we must act now without delay to avoid a global disaster and in the meantime probably create an even greater economic disaster than the one we are trying to avoid. In fact some of the claims have already been shown to be false and undermine the veracity of the entire case. It is those very attitudes that caused the Chernobyl disaster – operators 'cutting corners', failing to use common sense or think through the logical consequences of their actions and ending in a catastrophe equivalent to driving a vehicle without brakes.

We should not pollute the land or the sea unnecessarily nor should we clutter the Earth with millions of WPPs or build artificial lakes for HEPs in rainforests. That is not Earth friendly.

As James Lovelock states in his book "Gaia" [xxii], the *"..way to come to terms with gaia" "is to take the high tech road. It would require us to embrace science and engineering not reject them; we need their skills and inventions¹⁷ to lessen our impact on the Earth."* *"Now once more" "..we need the best technology. We need a*

portfolio of energy sources, with nuclear playing a major part."

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¹⁷ inventiveness

APPENDIX 1 - Power Density

The following table is reproduced from MasterResource” by Dr. Vaclav Smil^[xxiii]

Power Source	Power Density (W/m ²)	
	Low	High
Natural Gas	200	2000
Coal	100	1000
Solar (PV)	4	9
Solar (CSP)	4	10
Wind	0.5	1.5
Biomass	0.5	0.6

These power density values are based on the total power plant and the entire area occupied by the facility. A figure given for nuclear power has been obtained from “Illuminating the Future of Energy” by Professor D JC McKay as “about 1000 watts per square meter”

APPENDIX 2 - Capacity Factor of Wind Power (reproduced from ^[xxiv])

Table 1. Installed capacity and capacity factor for wind energy Data are for 2006 except where noted.

	installed capacity	mean power	capacity factor
	MW _e	MW _e	
Morocco (Amogdoul wind farm) ^[2]	60	23	38.1%
U.S. (total) ^{[3] (a)}	6740	1941	28.8%
U.K. (off-shore) ^{[4] (b)}	304	74	28.7%
U.K. (on-shore) ^[4]	1651	408	27.2%
Denmark (total) ^{[2] [6] (c)}	3128	755	24.1%
Spain (total) ^[2]	11615	2534	21.8%
Portugal (total) ^{[2] [7] (d)}	1022	202	19.8%
Netherlands (total) ^{[2] [8] (e)}	1219	236	19.3%
Germany (total) ^[5]	20622	3482	16.9%
India (total) ^{[2] [9] (f)}	4430	704	15.9%
Italy (total) ^{[2] [10] (g)}	1718	268	15.6%
Poland (total) ^[2]	153	22	14.6%
France (total) ^{[2] [11] (h)}	757	109	14.5%
World (total) ^{[2] [12] (i)}	59051	11559	19.6%

APPENDIX 3 - Safety

Paul Scherrer Institut. Switzerland table for accidents for electricity production ^[xxv] (≥ 5 immediate fatalities 1969 – 2000):

Energy chain	OECD		EU		non-OECD	
	Accidents	Fatalities	Accidents	Fatalities	Accidents	Fatalities
Coal	75	2259	11	234	102 1044 ^(a)	4831 18017 ^(a)
Oil	165	3789	58	1141	232	16494
Natural Gas	90	1043	24	230	45	1000
LPG	59	1905	19	515	46	2016
Hydro	1	14	0	0	10	29924 ^(b)
Nuclear	-	-	-	-	1	31 ^(c)

(a) First Line: Coal non-OECD W/OP China; second line China

(b) Banqiao and Shimantan dam failures together caused 26000 fatalities

(c) Latent fatalities are treated separately

Accident statistics for Chernobyl range from “1 million nearly killed” (new book on Environment News Service) through “could top a quarter of a million cancer cases” (Greenpeace) to possibly “half a million” (UK guardian newspaper). Despite all these claims the World Health Organisation stated (19 yrs after the accident) “As of mid-2005 however, fewer than 50 deaths had been attributed to radiation from the disaster, almost all being highly exposed rescue workers, many within months of the accident but others as late as 2004”. One of the most comprehensive reports is *Chernobyl’s Legacy: Health, Environmental and Socio-Economic Impacts* (IAEA) ^[xxvi]. The last of Chernobyl’s 4 reactors closed in 2000 -14 years after the accident. The Ukraine continues to invest in nuclear power and currently has 15 reactors which supply about 50% of the country’s electricity. New plants are planned for the future.

Recent **hydro** station accidents include:

- June 2009 accident at Svandalsflona Dam, Norway, killing 2 workers
- August 2009 an accident occurred at the Sayano-Shushenskaya Dam, Russia, killing 74 workers

Coal is generally regarded as the worst source of accidents for energy but the following is worthy of note:

"The low number of total deaths in the wind-power industry is undermined by the very low amount of power generated by wind. Adjusting for power production yields a surprising result. On a million-megawatt-hour basis, the wind-energy industry has averaged 0.0220 deaths compared with 0.0147 for coal over the years 2003 - 2008"¹⁸. Even adding coal's share of fatalities in the power-generation industry, which brings the rate up to 0.0164, still leaves wind power with a 34 percent higher mortality rate. For the record, the workplace fatality rate for wind also exceeds that for oil and gas on an equivalent-energy basis." (source [^{xxvii}])

Caithness Windfarms Information Forum (CWIF) 2010 [^{xxviii}] has produced a data base covering 915 accidents and listing 69 fatalities on wind farms from 1970 to 30 June 2010. It predicts that the number of accidents will increase as the number of turbines increases. The average number of accidents has increased from 16 accidents per year from 1995 – 1999 to 124 accidents per year from 2007 – 2009.

A Summary of Wind Turbine Incidents (up to June 2010) can be found on the CWIF Website

Website (Next Big Future)[^{xxix}] headed ***"Deaths per TWh for all energy sources: Rooftop solar power is actually more dangerous than Chernobyl"*** quotes statistics from various other sources including the (US) Bureau of Labor Statistics

The information presented confirms that nuclear power is the safest form of energy is about twice as safe as hydro (or 35 times depending on which part of the world you live in), 4 times safer than wind power (excluding offshore), 10 times safer than solar, about 100 times safer than natural gas, several hundred times safer than bio-fuels, almost 1000 times safer than oil and between 400 and 7000 times safer than coal depending on whether you are in the United States or China.

If more DIY enthusiasts embark on installing their own domestic wind generators (almost two billion solar panels) accidents could increase [^{xxx}]

"with the push for solar roof panels, we can expect to see hundreds more deaths occurring in the future as amateur installers take to the roofs. This includes the accident prone nature of performing regular maintenance on these solar cells by homeowners."

APPENDIX 4 - The Economics of Generating Electricity

The *"The Costs of Generating Electricity"* by the Royal Academy of Engineering is the most comprehensive study available for the UK. A table of the results can be found in the report[4]. The report shows that for the technologies studied the cheapest method of generating electricity is combine cycle gas turbine (CCGT) followed by nuclear¹⁹ cheaper than other technologies as follows:

Technique	Percentage more expensive than nuclear fission
Coal fired pulverised (coal) fuel (PF) steam plant	8.7%
Coal fired circulating fluidized bed (CFB) steam plant	13%
Coal-fired integrated gasification combined cycle (IGCC)	39%
Poultry litter bubbling fluidized bed (BFB) steam plant	195%
Wind turbines onshore without back up power	60%
Wind turbines onshore with back up power	135%
Wind turbines offshore without back up power	140%
Wind turbines offshore with back up power	213%
Marine technologies	187%

Open-cycle gas turbine (OCGT) plant is normally only used for peaking and would be too expensive for continuous operation.

The costs were based on

• **Capital expenditure**, i.e. the initial level of investment required to engineer, procure and construct the plant itself.

• **Fixed costs of operation and maintenance**, e.g. staff salaries, insurance, rates and other costs, which remain constant irrespective of the actual quantum of electricity generated;

• **Variable costs of operation and maintenance**, e.g. lubricating oil and chemicals, which are consumed in proportion to the actual quantum of electricity generated; and

• The **cost of fuel** (if applicable) consumed in generating electricity."

The conditions which apply to other countries will, of course, be different. A study by the Institute for Energy Research *"Levelized Cost Of New Electricity Generating Technologies"* provides data for US plants [^{xxxi}]

Washington Post Wednesday, July 21, 2010[^{xxxii}] quoted Senator Voinovich of Ohio as follows:

¹⁸ US Department of Labor, Bureau of Labor Statistics Census of Fatal Occupational Injuries (CFOI)

¹⁹ gas prices have risen since 2004 when the report was produced

"Voinovich would like his U.S. Senate colleagues to settle on a few core principles. He wants nuclear energy to be declared clean energy. That's not just rhetoric, because if nukes are included in any renewable electricity standards, they could compete "on a level playing field" with other renewable sources, Voinovich said."

"Voinovich also wants \$54 billion in loan guarantees for the construction of new plants, as well as tax incentives for construction, production and grants. He wants to accelerate development of small, modular reactors, with the federal government agreeing to a 50 percent cost-sharing with industry for \$100 million a year for ten years".

*"This country is not going to have reliable, affordable and clean energy without embracing more nuclear power, the Republican senator says. The nation's 104 operating nuclear plants produce 20 percent of this country's electricity but 70 percent of the electricity that's carbon-free, he says. Nuclear power costs less than **2 cents per kilowatt hour, compared with about 6.5 cents for wind and 15 to 20 cents for solar***, according to the senator, whose figures come from the American Wind Energy Association. And nuclear plants provide jobs -- 2,500 to 3,000 during construction and then 500 to 700 at each operating plant, he says."*

"In terms of nuclear power competing with wind and solar, I think there's no comparison," he said.

* Bolding not in original text.

APPENDIX 5 - Fast Neutron Reactors

Nuclear power will become fully sustainable with the use of fast reactors. There are of two types of reactors: fast neutron reactors that burn fissionable material including actinides such as fission products and other nuclear waste and fast breeder reactors which produce more fuel than they consume. Fast reactors have been in operation for nearly sixty years and have approximately 390 years of accumulated experience, there have been approximately 20 in the world some of which have been closed down.

History rarely develops as expected and uranium supplies proved to be more robust than anticipated with the net result that there was (and is) sufficient uranium for the foreseeable future. A further factor was the 'dash for gas' which made nuclear plants temporarily uncompetitive. Because of the expense and new technology nuclear plants were built in Asia but this took time.

China announced criticality of its first fast neutron reactor on 21/07/10 (a 20MWe sodium cooled reactor-CEFR) built by Russia's OKBM Afrikantov, OKB Gidropress, NIKIET and Kurchatov Institute. This follows China's agreement with Russia in Oct 2009 for the construction of two commercial 800MWe fast reactors. Construction of the BN-800 is well advanced due to start up in 2012. An 1800 MWe version, the BN-1800 is planned. The BN-600 reputed to be Russia's most successful reactor supplied power to the network for more than 28 years (Dounreay supplied power to the network for 20 years before it was closed down).

Japan is upgrading its existing fast reactors and has commissioned Mitsubishi to develop new reactors. Japan is keen to enhance its reactor technology since it has no natural resources to support its electricity generation. Japan is keen to develop breeder technology to become independent of outside suppliers. India is currently pursuing fast reactor technology to employ its vast stocks of thorium. France is embracing fast reactor technology under the EU *Sustainable Nuclear Energy Technology Platform* (SNETP) and plans to produce a large percentage of its electricity from fast reactors by 2050. Refer to WNA website [xxxiii]

APPENDIX 6 - Sustainability of Renewables

How sustainable are renewables?

Can renewable 'renew' themselves and provide a perpetual source of energy? For example there is no certainty that the **wind** will blow on any particular day, place or time. Even if the wind blows we don't know exactly how much electricity we can generate so the only way we can have a reasonable assurance is to oversize everything. Even then because of the uncertainties we require reliable back up power. This raises the question, "Do we need the wind power in the first instance?"

Moreover as James Lovelock has pointed out in his book[xxxiv] currents produce vortices. We have already seen that harvesting the wind does not always produce the expected results[xxxv]. How do we know that the currents will not shift. It has already been stated that climate change could alter the course of the Gulf Stream. Could it affect the wind currents as well?

Wind power may not be as renewable or as sustainable as some might think.

Solar power is an important source of energy and it is sufficiently reliable that the International Space Station (ISS) is powered by solar panels. According to Boeing, *"The 110 kilowatts of power for the ISS will be supplied by an acre of solar panels"* Unfortunately not all places on Earth get as much Sun as the ISS nor do they have an acre of space which is available to install solar panels. The ISS orbits the Earth 16 times per day. Each orbits takes approximately 90 minutes, 45 minutes in sunshine and 45 minutes in darkness so that it has a maximum of 45 mins without primary energy. Many countries such as Britain (especially the north of Scotland) get very little sunshine. There is even less light in winter when the Sun is low in the sky for a few hours and there is a weak grey light during the day. Solar energy is definitely not renewable or sustainable in the North of Scotland (where people are advised to take regular supplements of vitamin D because of the lack of Sun).

Hydro power is the greatest form of renewable energy and is responsible for approximately 16% of the world's energy. A few random searches on the internet reveal that all is not well:

• <i>Understanding drought in the Winnipeg River Basin, Manitoba</i>	• <i>Feb 2008 – Chile drought raises likelihood of power rationing</i>
• <i>Drought response South Carolina: reduces the availability of low-cost hydroelectric power to consumers</i>	• <i>Jan 2010 – Drought imperils Venezuela's electric power</i>
• <i>Jan 2005 Uganda prolonged drought affects hydroelectric power</i>	• <i>Mar 2010 – Drought in Philippines forces blackouts</i>
• <i>2006-2007 Drought affecting US power production</i>	• <i>Mar 2010 – China's hydroelectric power under a historic drought</i>
• <i>April 2007 Drought threatens Australia's Hydropower Scheme</i>	• <i>May 2010 – China's experiment with hydro power has been a disaster</i> ^{xxxvi}

Despite spending huge amounts of money subsidising hydro electric schemes China has been hit by massive droughts which reducing power output by 69% the dams are making the drought even worse because the operators are focused almost solely on power generation rather than water conservation. Whilst some areas have been affected by drought the Three Gorges dam is being severely tested due to massive floods which have already killed many people.

It appears normal to blame 'climate change' and 'global warming' but it is not impossible that some of them could have been brought on by building dams and diverting rivers in the first place. For example it is no secret that the flow of water in the Mekong River in Vietnam has been affected by the dams upstream.

Building large artificial dams, diverting rivers, flooding large areas of land are bound to have an effect on the Earth's regulating mechanisms. The cause of much of our problems may be our own interference with nature. The latest plan by Brazil is to build dams in the Amazon basin to ensure that they will not suffer the same power crisis as they did from drought in 2001 "**Brazil to flood Amazon rainforest for hydroelectric power**"^{xxxvii} "Brazil's plans to dam two rivers in the Amazon basin to generate power threaten a treasure trove of animals and plants in a region with one of the world's richest arrays of wildlife, environmentalists say."

It is more than possible that the very methods that some are advocating which are supposed to halt 'global warming' and be the solution to 'climate change' are in fact more damaging to the environment than would otherwise be the case. Hydro, wind farms and biomass all take their toll on the environment, changing the ecology and upsetting the balance of nature, the bigger the scale that we do this the greater the damage.

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