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The Role of Nuclear Power in the Option Zero Emission Technologies for Fossil Fuels

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ABSTRACT

The energy sector is one of the main sources of greenhouse gas (GHG) emissions particularly carbon dioxide (CO_2) increasing concerns due to their potential risk to induce global warming and climate change.

The Parties having signed the Kyoto Protocol in December 1997, committed to decrease their GHG emissions. The Protocol states that countries shall undertake promotion, research, development and increased use of new and renewable forms of energy, of carbon dioxide sequestration technologies and of advanced and innovative environmentally sound technologies. The one significant option that is not specifically mentioned is nuclear energy which is essentially carbon-free.

There are a number of technical options that could help reducing, or at least slowing the increase of, GHG emissions from the energy sector. The list of options includes: improving the efficiency of energy conversion and end-use processes; shifting to less carbon intensive energy sources (e.g. shifting from coal to natural gas); developing carbon-free or low-carbon energy sources; and carbon sequestration (e.g. planting forests or capturing and storing carbon dioxide).

It must be pointed out that nuclear power is one of the few options that are currently available on the market, competitive in a number of countries, especially if global costs to society of alternative options are considered; practically carbon-free; and sustainable at large-scale deployment.

The nuclear power could play significant role in alleviating the risk of global climate change. The main objective of the article is to present sequestration options, their cost evaluation as well as comparation with alternative possibilities of nuclear energy production.

1 INTRODUCTION

The surface temperature of the Earth is growing. It has risen by 0.6 degrees Celsius over the past 100 years. There was a warming trend from the 1890s to the 1940s, followed by a cooling trend from the 1940s to the 1970s, and the temperatures have been rising rapidly ever since.

A natural greenhouse effect contributes to warming. Greenhouse gases trap heat, and thus warm the earth because they prevent a significant proportion of infrared radiation from escaping into space. Concentration of greenhouse gases, especially CO_2, have increased substantially since the beginning of the industrial revolution.

There are only two ways to stabilize concentration of greenhouse gases. One is to avoid emitting them in the first place and the other is to try to capture them after they have been created. There are problems with both approaches. Great progress is being made in terms of technology, but cost-effective ways to capture carbon emissions at their source have not been developed yet; although there is some promising work is currently in progress.

2 KYOTO PROTOCOL

The Kyoto Protocol is an agreement made under the United Nations Framework Convention on Climate Change (UNFCCC). Countries that ratify this protocol commit to reduce their emissions of carbon dioxide and five other greenhouse gases, or engage in emissions trading if they maintain or increase emissions of these gases.

The Kyoto Protocol covers more than 163 countries globally and over 65% of global greenhouse gas (GHG) emissions.

Governments are separated into two general categories: developed countries, referred to as Annex 1 countries, who have accepted GHG emission reduction obligation and developing countries, referred to as Non-Annex 1 countries who have no GHG emission reduction obligations. Any Annex 1 entity failing to meet its Kyoto targets is subject to a fine.

By 2008-2012, Annex 1 countries have to reduce their GHG emissions by around 5% below their 1990 levels. For many countries, such as the EU member states this implies to some 15% below their expected GHG emissions in 2008.

2.1 Status of the Agreement

The United States and Australia have signed but refused to ratify it. The signature alone is mostly symbolic, as the protocol is non-binding unless ratified.

The Australian government along with the United States agreed to sign the Asia Pacific Partnership on Clean Development and Climate. The Asia-Pacific Partnership on Clean Development and Climate, known as AP6, is an international non-treaty agreement among Australia, India, Japan, the People's Republic of China, South Korea, and the United States announced July 28, 2005 at an Association of South East Asian Nations (ASEAN) Regional Forum meeting and launched on January 12 2006 at the Partnership's inaugural Ministerial meeting in Sydney. Countries agreed to co-operate on development and transfer of technology which enables reduction of greenhouse gas emissions.

Member countries account for around 50% of the world's greenhouse gas emissions, energy consumption, GDP and population. Unlike the Kyoto Protocol which imposes mandatory limits on greenhouse gas emissions, this agreement allows member countries to set their goals for reducing emissions individually, with no mandatory enforcement mechanism. This has led to criticism that the Partnership is worthless, by other governments, climate scientists and environmental groups.

India and China have ratified the Kyoto protocol but are not required to reduce carbon emissions under the present agreement despite their relatively large populations.

The current President, George W. Bush, has indicated that he does not intend to submit the treaty for ratification, not because he does not support the Kyoto principles, but because of the exemption granted to China (the world's second greatest emitter of carbons) and also the strain he believes the treaty would put on the economy. The USA does not support the split between Annex I countries and others.

Canada feels a fear that since US companies will not be affected by the Kyoto Protocol that Canadian companies will be at a disadvantage in terms of trade.

On April 25, 2006, Canada announced that it would have no chance of meeting its targets under Kyoto, and would instead look to participate in Asia Pacific Partnership on Clean Development and Climate.

3 CCS-CO_2 CAPTURE AND STORAGE

Technologies for capturing CO2 hold great potential for avoiding global warming and preventing the release of green gases into the atmosphere. The present article takes up those technologies and their status.

According to the predictions of IEA World Energy Outlook Reference Scenario, by 2030 CO2 emissions will have increased by 63% on today's level, which exceeds by almost 90% the 1990 levels.

3.1 Capture and Storage

CO_2 capture and storage (CCS) involve three different processes, capturing CO_2, transporting it by pipeline or in tankers and third storing-underground in deep saline aquifers, depleted oil and gas reservoirs or unmineable coal seams. Further development is needed.

Three main groups of technologies which can be used to capture CO_2 from power plants:

- CO_2 capture from flue gas,
- Fuel reforming into hydrogen and CO_2, followed by capture from the concentrated and pressurized gas,
- The use of oxygen for combustion which results in a concentrated CO_2 flue gas.

CO_2 can be captured either before or after combustion using a range of existing and emerging technologies. In conventional processes, CO_2 is captured from the flue gases produced during combustion(post-combustion capture). It is also possible to convert the hydrocarbon fuel into CO_2 and hydrogen, remove CO_2 from the fuel gas and combust the hydrogen(pre-combustion capture).

3.2 CO_2 Transportation Technology

While pipeline transport is an established technology, the proper siting of CCS projects can reduce the need for an extensive transportation system. Given potential pipeline siting constraints and transportation distances of hundreds of kilometers, a CO_2 transportation 'backbone' may be needed to which multiple power plants and a number of storage sites can be connected. Such a system would allow transportation over longer distances at acceptable cost. Transporting CO_2 by ship is also considered as an option.

3.3 CO_2 Storage Technology

Underground CO_2 storage is deep saline aquifers, in depleted oil and gas reservoirs and in un-mineable coal seams seems the only realistic option in the short and medium term, due to reasons such as environmental risk and acceptance problems for oceanic storage as well as cost and immature technology status for above-ground carbonate storage. Oceanic storage is problematic given the unknown environmental impacts.

3.4 The Risk and Effect of CO_2 Leakage back into the Atmosphere

All three storage options-deep saline aquifers, depleted oil and gas reserves and unmineable coal seams need more proof on a large scale. The technology to store CO_2 underground should be considered proven technology. The problem is whether the CO_2 will leak from underground storage sites back into the atmosphere. CO_2 is not toxic, but CO_2 can be dangerous in high concentrations as it can cause suffocation due to lack of oxygen. There are cases where natural CO_2 emissions from underground have created locally dangerous situations.

3.5 The Cost of CCS

The total cost of CCS could range from 50 to 100 USD per tonne of CO_2. This could drop significantly in future. By 2030, these costs should go down to 25-50 USD per tonne of CO_2 compared to the same process without CCS.

The cost for CCS can be split into cost of capture, transportation and storage. Current estimates for large-scale capture systems are 25 to 50 USD per tonne of CO_2 but are expected to improve as the technology is developed and deployed. If future efficiency gains are taken into account, costs could fall to 10-25 USD/t CO_2 for coal-fired plants and to 25-30 USD/t CO_2 for gas-fired plants over the next 25 years.

With CO_2 transportation, pipeline costs depend strongly on the volumes being transported and on the distances. Large-scale pipeline transportation costs range from 1-5 USD/t CO_2 per 100km. If CO_2 is shipped over long distances rather than transported in pipelines, the cost fails to around 15-20 USD/t CO_2 for a distance of 5,000 km.

The cost of CO_2 storage depends on the site, its location and method of injection chosen. In general, at around 1-2 USD per tonne of CO_2, storage costs are marginal compared to capture and transportation costs.

4 NUCLEAR OPTION

MIT study in 2003 on The Future of Nuclear Power showed that the nuclear power option would succeed if the technology demonstrated better economics, improved safety, successful waste management, and low proliferation risk, and if public policies place a significant value on electricity production that does not produce CO_2.

The article is considering each mentioned conditions from present day.

4.1 Economics

Dramatic changes in fossil fuel prices occurred in the period from 2003 to 2006. The prices of all fossil fuels hinge on oil price. The oil price in 2003 was around 30$/barrel, and in 2006 63$/barrel. Fuel prices of coal and gas have increased; coal from 2.115 to 2.69 $/GJ, gas from 5 to 6.26$/GJ, 2003 and 2006, respectively.

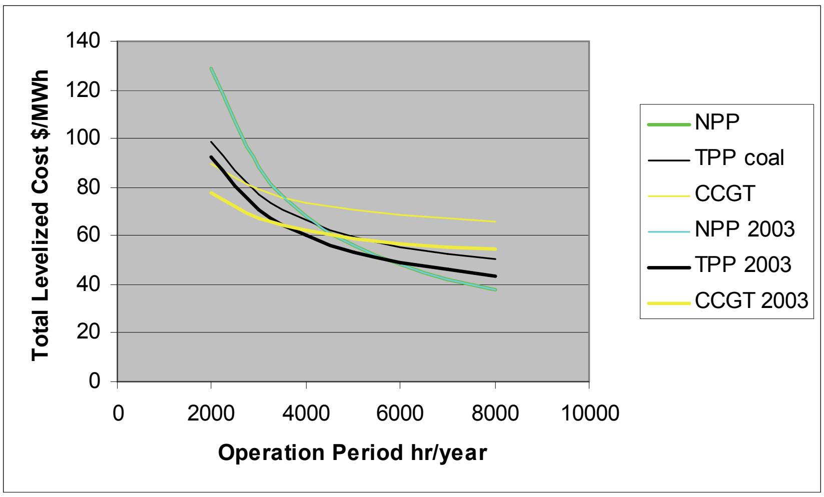

Figure 1: Total Levelized Cost for the Year 2003 and 2006

A model is constructed to evaluate and compare total levelized cost of electricity of nuclear power plants, coal and natural gas plants over 40 years. Cost of fuel, waste, decommissioning, operation and maintenance, and annuity are taken into consideration.

Table 1 illustrates some of the significant input parameters of the model. The coal price includes transportation, loading and unloading.

The model results based on input parameters make clear that electricity from nuclear power plants today is competitive with electricity from thermal power plants as well as CCGT plants above 4000hr/year.

Table 1: Input Parameters of the Model

Input parameters	Nuclear power plant	Thermal power plant (coal)	CCGT
Overnight cost $/kWe	2000	1500	750
Construction time (years)	5	4	2
Plant life (years)	40	40	40
Plant net capacity (MWe)	1000	350	350
Capacity factor (%)	85	85	85
Heat rate (kJ/kWh)	11555	10400	7428
Fuel cost ($/GJ)	0.5	2.69	6.26
Nuclear waste fee (mills/kWh)	1	0	0
Fixed O&M ($/kWe/yr)	63	23	16
Variable O&M (mills/kWh)	0.47	3.38	0.52
Decommissioning cost ($million)	300	0	0
Inflation rate (%)	0	0	0
Interest rate (%)	5	5	5
Real fuel escalation (%)	0.5	0.5	1.5
O&M real escalation rate (%)	1	1	1
Discount rate (%)	6	6	6
Yearly operation period (h/year)	2000:8000	2000:8000	2000:8000

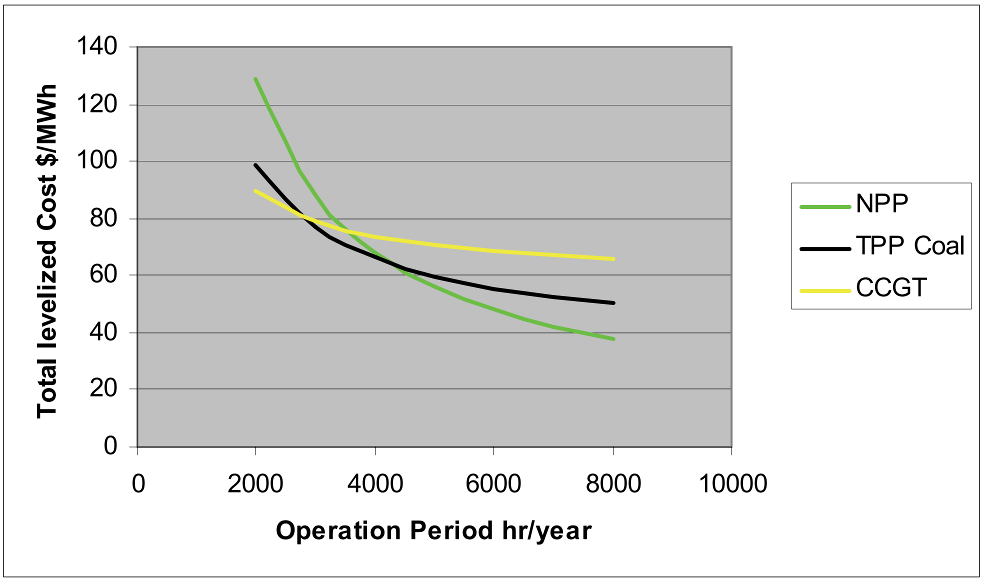

Figure 2: Total Levelized Cost of Electricity for Different Power Plants
Nuclear fuel 0.5$/GJ, Coal 2.69$/GJ, Natural gas 6.26$/GJ

It is examined how the carbon taxes, the cost of CCS alter position of each plant. First, the change of fuel price due to carbon taxes was assumed. The fuel price of thermal power plant(coal) rises from 2.69 to 4$/GJ, gas from 6.26$/GJ to 6.86$/GJ.

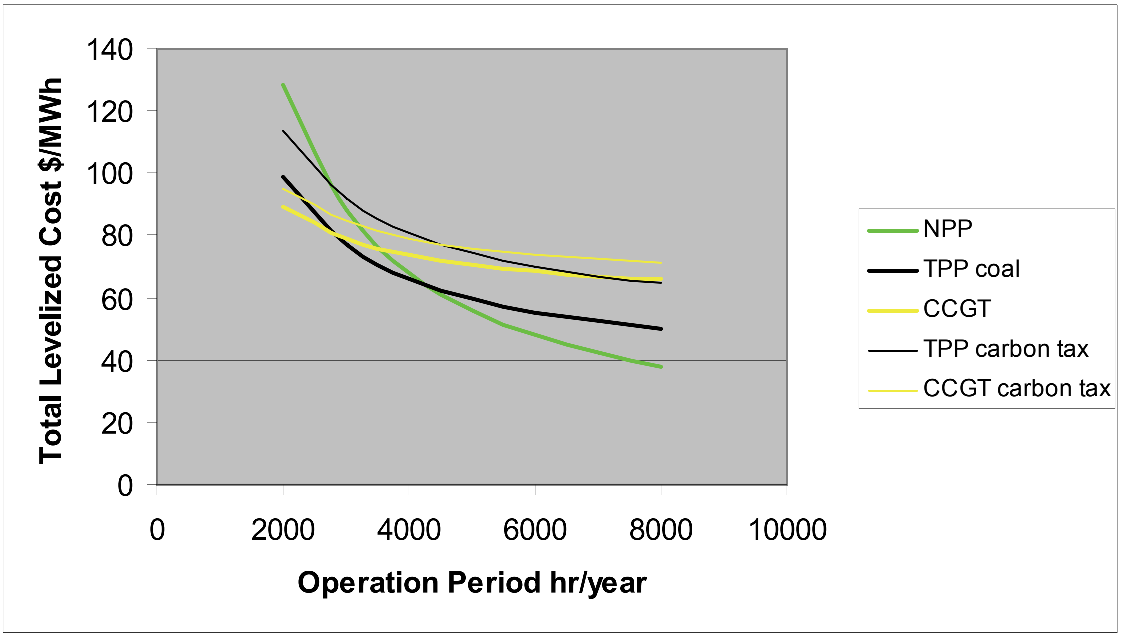

Figure 3: Total Levelized Cost of Electricity-Carbon Taxes included (1.2$/GJ-coal, 0.6$/GJ-gas)

Taking the carbon tax, nuclear option is free of competition even at very low number of operation hours. Thereafter, the impact of CCS is considered. The cost of CCS ranges from 50 to 100 $/tonne of CO_2, only the lowest cost was taken into account.

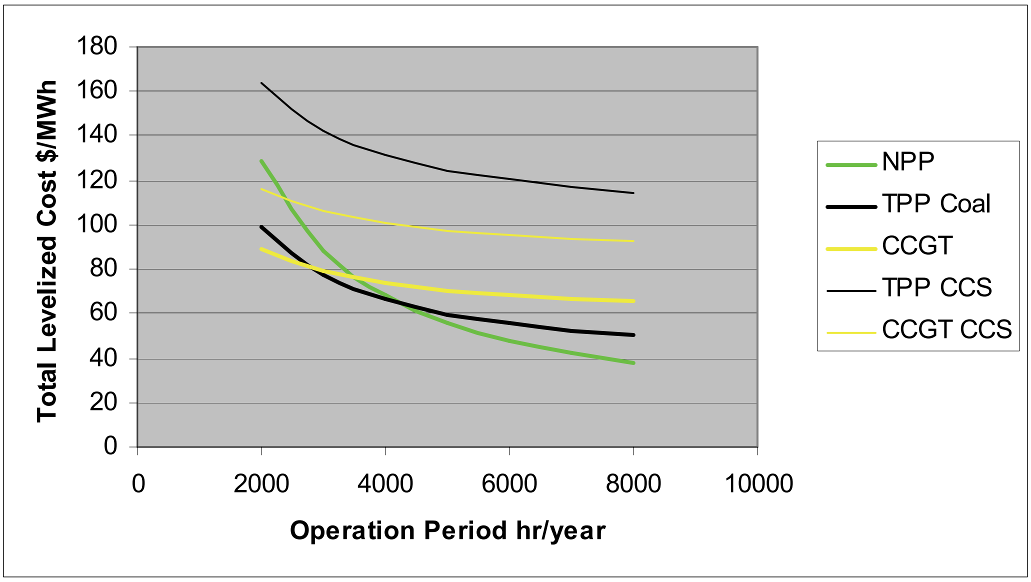

Figure 4: Total Levelized Cost-the Cost of CCS included (50$/tonne CO2)

4.2 Safety

Safe operations of the entire nuclear fuel cycle are very important. It is assumed that there will be three-fold increase of nuclear fleet capacity by 2050 in the world. The goal should be to carry out this large expansion without increasing the frequency of serious accidents. This can be accomplished by means of both evolutionary and new technologies.

Advances in science, engineering, and plant design have made nuclear power plants far safer than ever before – safety has been of primary concern for plant workers and managers.

As terrorists have demonstrated their ability to inflict catastrophic damage, the fear is reasonable. Nuclear plant safety has considered natural external events, such as earthquakes, tornadoes, floods and hurricanes. Terrorist attack by fire or explosion is analogous to external natural events in its implication for damage and release of radioactivity. The strength of containment buildings and structures presents a major obstacle and hardened target for attack. EPRI (Electric Power Research Institute) carried out an evaluation of aircraft crash and NPP structural strength, concluding that U.S. containments would not be breached.

4.3 Waste Management

The management and disposal of high-level radioactive spent fuel from the nuclear fuel cycle is one of the most intractable problems facing the nuclear power industry throughout the world. Most countries with nuclear power programs and all the major ones have adopted as their preferred technical approach to the final disposal of high-level waste the emplacement of sealed waste bearing canisters in mined structures ("geological repositories") hundreds of meters below the earth's surface. Many independent experts have concluded that geologic respositories will be capable of safety isolating the waste from the biosphere. However, implementation of this method is a highly demanding task that will place great stress on operating, regulatory and political institutions. No country has yet successfully implemented an operating repository for high-level waste and all have encountered difficulties with their programs. In many countries public and political opposition to proposed nuclear waste facilities and to the transportation of nuclear waste by road or rail has been intense and public opinion polls reveal deep skepticism around the world about the technical feasibility of safely storing nuclear waste over the long periods for which it will remain hazardous. Many people think that no new nuclear power plants should be built until the waste issue has been resolved. In several major nuclear countries laws have been enacted whose practical effect will be to slow or even prevent the licensing of future nuclear power plants in the absence of demonstrable progress towards waste disposal.

Although geologic disposal is the announced technical strategy in almost every country, there are big differences in how countries are planning to implement it. So far only three countries, Finland, Russia and the U.S., have identified specific sites for their repositories.

The U.S. high-level waste management program has focused almost exclusively on the proposed repository site at Yucca Mountain in Nevada. Although the successful commissioning of the Yucca Mountain repository would be a significant step towards the secure disposal of nuclear waste, it is believed that a broader, strategically balanced nuclear waste program is needed to prepare the way for a possible major expansion of the nuclear power sector in the world.

4.4 Nonproliferation

Nuclear power should not expand unless the risk of proliferation from operation of the commercial nuclear fuel cycle is made acceptably small. Nuclear power can expand as envisioned in global growth scenario with acceptable incremental proliferation risk, provided that reasonable safeguards are adopted and that deployment of reprocessing and enrichment are restricted. The nonproliferation issues arising from the global growth scenario are brought into sharp focus by assumption of deployment of nuclear capacity. If the proliferation regime is not strengthened, the option of significant global expansion of nuclear power may be impossible, as various governments react to real or potential threat of nuclear weapons proliferation facilities by fuel cycle development. Responsible governments must control, to the extent possible, the know-how relevant to produce and process either highly enriched uranium or plutonium. The proliferation concern has led, over the last century, to many international institutions and agreements, none of which have proved entirely satisfactory.

Three issues are of particular concern: existing stocks of separated plutonium around the world that are directly usable for weapons; nuclear facilities, for example in Russia, with inadequate controls; and transfer of technology, especially enrichment and reprocessing technology, that bring nations closer to a nuclear weapons capability. An international respone is required to reduce the proliferation risk. The response should re-appraise and strengthen the institutional underpinnings of the IAEA safeguards regime in the near term, including sanctions and the response should guide nuclear fuel cycle development in ways that reinforce shared nonproliferation objectives.

5 CONCLUSION

The analysis has shown that nuclear energy is competitive today even without considering carbon taxes and the cost of CCS.

Nuclear energy enjoys support of many different countries. In 2005 the president Bush signed the energy bill providing loan incentives, production tax credits and federal risk insurance for builders of new nuclear plants. Loan incentives will give investors confidence that the Federal government is committed to the construction of nuclear power plants. Production tax credits will reward investments in the latest advanced nuclear power generation. Federal risk insurance for the first six new nuclear power plants will help protect builders of these plants against lawsuits, bureaucratic obstacles, and other delays beyond their control. The U.S.A is urging the advancement of nuclear energy as part of a diversified U.S.

energy policy that will make America less dependent on foreign sources of oil and more dependent on renewable sources of energy.

Unit 3 at Olkiluoto in Finland, the first of a kind EPR was expected to enter commercial operation in May 2010. Canada announced plans to investigate building new reactors, U.K. came out in support of nuclear.

Bulgaria approved the construction of the second Bulgarian nuclear power plant at Belene on the Danube. The new plant would have a maximum capacity of 2000 megawatts, with two VVER-type reactors using light water under pressure. The plan is that the first of these will go into operation in 2011.

It must be emphasized that safety and waste improvements were made in nuclear industry. Paying carbon taxes is the solution; the environment will still be jeopardized. Technologies for capturing CO_2 are great potential for avoiding global warming and prevention of releasing green gases to atmosphere, however very expensive and not proven yet. There is no better solution for decreasing CO_2 emissions than nuclear power.

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