

Ethics and Nuclear Energy Technology

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PREFACE

The report stems from the work of many authors and scholars. Much of this was completed under the framework of Working Group 12 established by the Regional Unit in Social and Human Sciences in Asia and the Pacific (RUSHSAP) at UNESCO Bangkok under the Ethics and Climate Change in Asia and the Pacific (ECCAP) project. The ethics of nuclear energy technology, as one of the applications of science and technology, is one of the most contentious issues facing human society globally. There are benefits and risks, and how will society balance these? Some countries are adopting the technology to produce electricity, and others are rejecting it. The UN aims to encourage science and value-based discussions on environmental ethics to produce substantive cross-cultural and multidisciplinary outputs that will be relevant for long-term policy making.

The aim of the ECCAP project is not to formulate universal economic or political plans of how to deal with these issues. Rather, the working groups of the project aim to increase awareness and discussion of the complex ethical dilemmas related to energy and the environment, and to identify scientific data, and available ethical frameworks of values and principles for policy options that have proven useful in facing the challenges in certain communities and countries. The report was developed by a working group with members from across the region, who participate as individuals in the highest standards of intellectual vigour and integrity, integrating engineers, philosophers, policy makers, experts, youth, and persons of many different cultural backgrounds and experiences. The reports are subject to ongoing open peer review, and the principal authors are listed.

There is ongoing discussion of numerous reports on the yahoo group, unesco_eet@yahoogroups.com, that are in various stages of drafting. For all reports, drafts and outlines of others, and specific requests for further case studies and analyses, please examine the working group webpages which list the members, and the overall website, <http://www.unescobkk.org/rushsap/energyethics>. The report writers thank all members of the ECCAP project, and in particular WG12, and Ms. Nobuko Yasuhara for comments. Feedback and comments are invited to Dr. Darryl Macer, Director, eubios Ethics Institute, or email darryl@eubios.info

Darryl Macer

ACRONYMS

ASEAN:	Association of Southeast Asian Nations
CBD:	Convention on Biodiversity
ALARA:	“As low as reasonably achievable”- a concept by the ICRP for radiation risk assessment and management described in detail and substantiated in the recommendation of the ICRP of 1990.
AREVA:	French public multinational industrial conglomerate founded in 2001
Bq:	Becquerel; unit of radioactivity. Defined as the activity of a quantity of radioactive material in which one nucleus decays per second.
Btu:	British thermal unit. Defined as the amount of energy needed to raise the temperature of 1 pound of water by 1 degree Fahrenheit at 1 atmosphere of pressure.
CANDU:	Canada Deuterium Uranium Reactor uses uranium dioxide pellets with natural uranium (enriched with 0.7% ²³⁵ U)
CCGT:	Combined Cycle Gas Turbine Power Plant.
CRIIARD	Commission de Recherche et d’Information Indépendantes sur la Radioactivité (A specialized French NGO for the analysis of radioactivity in the environment, http://www.criirad.org/)
Cs:	Cesium (radioactive element, ¹³⁷ Cs has a half-life of 30.23 years). One of the principle sources of radiation in the Chernobyl nuclear plant accident.
CTBT:	Comprehensive Test Ban Treaty
D:	Deuterium (non-radioactive isotope of Hydrogen (H); used in heavy water as a moderator in a PHWR/CANDU reactor)
DU:	Depleted Uranium
EPA:	Environmental Protection Agency, USA
ECCAP:	Ethics and Climate Change in Asia and the Pacific (Project)
FBR:	Fast Breeder Reactors
FAO:	Food and Agriculture Organization of the United Nations
GHG:	Green House Gas
GNEP:	Global Nuclear Energy Partnership
I:	Iodine (radioactive isotope ¹³¹ I has a half-life of 8.07 days). One of the principle sources of radiation in the Chernobyl nuclear plant accident.
IAEA:	International Atomic Energy Agency
ICRP:	International Council for Radiation Protection
IEA:	International Energy Agency
IGCC:	Integrated Gasification Combined Cycle Power Plant.
IMF:	International Monetary Fund
IPCC:	Intergovernmental Panel on Climate Change
kWh:	Kilo watt-hour is the amount of power generated or consumed in 1 hour
mSv:	Measure of the “dose” or amount of radiation received by people
MOX:	Mixed oxide fuel
NEA:	Nuclear Energy Agency; a specialized agency within the OECD
NEI:	Nuclear Energy Institute
NGO:	Non-Governmental Organization

NPP: Nuclear Power Plant
NPT: Non-proliferation Treaty
NRDC: Natural Resources Defense Council
OECD: Organization for Economic Cooperation and Development
PHWR: Pressurized Heavy Water Reactor (also known as CANDU) use heavy water as the coolant.
Pu: Plutonium (radioactive element, Pu-239 isotope is derived from ^{235}U in some reactors).
PWR: Pressurized water reactors. PWRs comprise the majority of nuclear power plants. Can be classified as LWR's (light water reactors) that use light water as the primary coolant, and BWR's (boiling water reactors) that use boiling water as the coolant.
Th: Thorium (radioactive element, considered as an alternate fuel in breeder reactors).
U: Uranium (radioactive element, ^{235}U isotope used as fuel in nuclear reactors). Nuclear fuel is enriched with 2-5% ^{235}U .
 U_3O_8 : Triuraniumoctaoxide; Uranium ore commonly called uranium oxide or Pitchblende. Mined as a source of uranium for nuclear fuel.
UNDP: United Nations Development Programme
UNEP: United Nations Environmental Programme
WANO: World Association of Nuclear Operators
WNA: World Nuclear Association

Executive Summary

This report addresses a topic of great current attention, the ethics of nuclear energy technology. As we consider the ethics of science and technology, nuclear power has always been dreaded as something risky, while also being held in wonder as a source of energy to overcome the energy gap that is faced by many persons in the world living in poverty. As the world is rethinking the safety of nuclear energy technology following the meltdowns in reactors at Fukushima Daiichi nuclear power plant in Japan, this report takes a balanced approach to the issues associated with nuclear energy technology in general.

There are a number of ethical issues that are discussed and examples from around Asia are given in particular, along with a comparison of lessons from Chernobyl and Fukushima. Although Fukushima was triggered by a large earthquake and tsunami, the dangers of the tsunami and of losing electricity to cool the reactors, were known. Human error at individual and systemic level seem also to be involved. There are also case studies exploring policies in People's Republic of China, India, Indonesia, Philippines and Kazakstan, among other countries, embedded through the report.

A dozen policy options are presented including the need for greater transparency, independent media, rapid reporting, and consideration of the economic implications of nuclear energy over a long term frame. As the technology has been argued to be more sustainable than fossil fuel based electricity generation, the ethics of externalization of costs and risks needs to be considered across the full range of energy options.

There is discussion of public opinion and the significant decrease in support for nuclear energy technology for electricity generation, although its benefits in other areas are accepted. The report discusses some of the issues of proliferation in passing, but focuses on peaceful uses of nuclear energy technology, calling for more research into methods to assess the health and environmental impacts of radioactivity that will allow more informed choices by each nation, and the public, for the future energy needs of their communities.

1. Nuclear Energy and Climate Change

1.1 Nuclear Energy

Nuclear energy is one of the energy options used today across the world that could be expanded for the future because in its normal day-to-day operations it does not produce significant CO₂ and other pollutants into the atmosphere, which cause global warming. At the same time the safety of nuclear energy has been one of the major public topics of discussion in 2011 following the Fukushima accident, which has revived the fears that emerged after Chernobyl accident in 1986. In the Ethics in Climate Change and Asia and the Pacific (ECCAP) project this is a comparative analysis of the ethics of nuclear energy compared with other energy options, including renewable energy.¹

Nuclear energy technology can be applied for many different purposes. These include electricity production, weapons manufacture, production of medical isotopes, transportation (ranging from military submarine propulsion and space-based vehicle propulsion), industry (e.g., food irradiation and production of electronic components, sterilization of insect vectors that transmit diseases), and basic and applied research. While issues arising from all of these applications have significant consequences for society, this report focuses on ethical issues of energy production relating to climate change. The analysis in this report focuses on energy technologies for general consumption.²

This report on the ethics of nuclear energy does not conclude by adopting one recommendation on whether nuclear energy should be used or not, and to what extent. This ethical analysis is not intended to provide single answers to specific policy options for contextually-sensitive decisions that each government needs to make, rather it aims to provide a framework for ethical analysis that can be used to examine nuclear energy technologies that can be applied for various cases and situations. Such analysis can be extended for particular situations and contexts. The report attempts to examine aspects of nuclear technology with a balanced scientific perspective.³

Examining these issues at a more fundamental level and analyzing policy options can reach greater consensus reached on policy regarding nuclear energy, which may reduce internal and international political tensions, which often hamper clear consideration of the ethics of nuclear energy. Mutual understanding of different perspectives, realizing that each perspective carries its own set of assumptions, which can be enriched with mutual recognition of other perspectives in order to discuss and implement policy.

1 This report was developed initially under the Ethics of Energy Technologies in the Asia and the Pacific (EETAP) project focusing on nuclear energy as one of the energy options to produce electricity, and included under the ECCAP project as the project name changed.

2 This is the vast majority of nuclear technology in use today. The report does not cover sources of transportation energy, for example, for submarine propulsion systems, nor applications of nuclear technologies for medical uses or the food industry. We therefore have foregone in-depth discussion of many of the ethical issues of these applications.

3 Science in terms of this report refers to both natural and social sciences.

1.2. Ethics and Nuclear Energy Technology

The importance of nuclear energy technology is not limited to its widespread use nor the complex political and economic issues often present. The ethical analysis applied in this report is pluralistic, which “accepts different moral convictions and background while at the same time suggesting that a consensus on basic principles and rules in a certain social context can, and should, be reached” (Crane and Matten, 2007).

Pluralistic approaches have often been applied in bioethics, business ethics, and environmental ethics. A *prima facie* approach to resolving a bioethical dilemma is often used in conjunction with ethical principles such as autonomy, beneficence, non-maleficence, and justice (Beauchamp and Childress, 2001). Ethics applies various ethical theories to choices including environmental issues, but a most significant issue is who or what is defined as a moral agent for ethical considerations. There are various schools of thought in environmental ethics including enlightened (or weak) anthropocentrism, animal liberation/rights theory, biocentrism, and ecocentrism (Yang, 2006; Rai et al., 2010).

A comprehensive analysis of the ethical principles and goals adopted in international environmental instruments is in a parallel ECCAP report (Rai et al., 2010).⁴ As stated in that report (Rai et al., 2010), there are a variety of views of the world, and depending on the view that people have there will be different conclusions. The ECCAP working groups 2 and 3 focus on examining different world views of nature, and visions of the future, respectively, which affect the balancing of the timescale and magnitude of risks and benefits expected from nuclear energy.

The academic literature is also replete with proposals for specific principles. For example, Robertson (2009) proposed principles for ethics of nuclear energy including the principle of no absolutes, which also applies to general ethics, as a certain ethical aspect that cannot be either right or wrong. This includes: the principle of no absolutes, principle of no acceptable risk, principle of no free lunch, principle of alternatives and consequences, principle of risk optimization, principle that good intentions are not good enough, principle that facts matter, and the principle of quantification where possible.⁵ The principle of non-maleficence is very important to people’s fears of nuclear technology, and is an accepted principle in international law. Many of the discussions that follow in this report are based on the application of basic principles of bioethics, including autonomy of persons to decide their energy choices, justice, non-maleficence and beneficence, to the debates in nuclear energy as an energy option for the future.

4 All ECCAP reports are openly available on the project website: <http://www.unescobkk.org/rushsap/energyethics>

5 Some of these are discussed in section 5.8.

1.3 Nuclear Energy Technology in a Global Context

World total primary energy supply (TPES) is an amount of energy before conversion to end-use energy. Energy from nuclear technology accounts for about 6 % of the World's TPES. Hydropower (2.2%) together with other (0.7%) renewable energy, such as solar, geothermal and wind, account for less than 3 percent of World TPES (Figure 1).

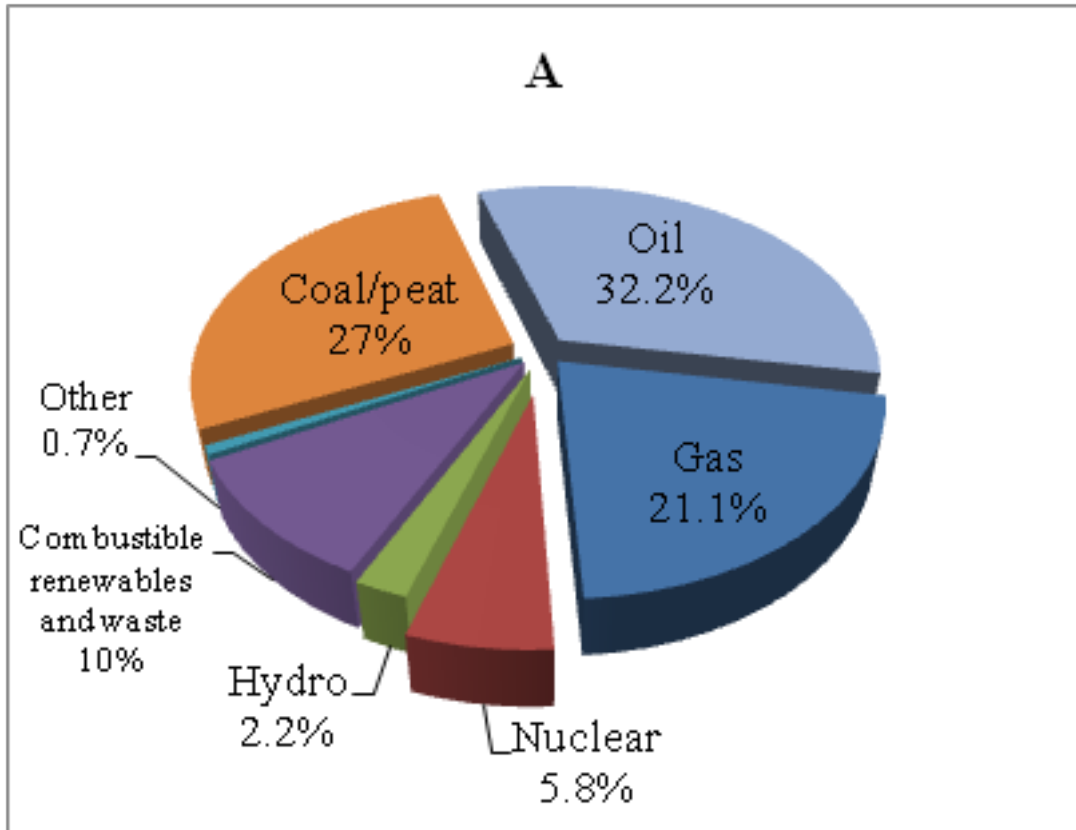


Figure 1: World total primary energy supply by fuel (12267 million tons of oil equivalent)

Created using data from "Key World Energy Statistics 2010", IEA.

If we account the electricity produced by fuel, that is, conversion of original physical units into a common unit of measurement like heat or electricity, the share of nuclear energy in the final consumption is significantly higher contributing up to 13.5% compared to its primary input of 5.8%. Coal dominates the world electricity production with a 41% share, over gas, hydropower, nuclear and oil (Figure 2).

Different methodologies and metrics are applied in accounting the primary energy sources. According to the substitution method (also referred as conventional fuel equivalent), that is an amount of fossil fuel which would have been necessary to generate an identical amount of electricity in a conventional fossil fuel thermal power plant.⁶ The electricity equivalents are at a rate of 0.086 TOE (tons of oil equivalent) =

6 Energy Statistics: Definitions, Units of Measure and Conversion Factors. ST/ESA/STAT/SER.F/44. p.19. UN Statistical Office, New-York, 1987. See also, IEA, Statistics menu.

0.123 TCE (tons of coal equivalent) = 3.6 MJ (Mega Joule (10^6)) = 1MWh (Megawatt hours (10^6)).⁷ The calculation of the primary energy equivalent is based on efficiency conversion. Giving the fact that the amount of heat generated in nuclear reactors is not always known, the estimated 33% is an average conversion efficiency for nuclear energy (it ranges from 29% - 35% according to EIA, 33% by IEA and UN, and 38% by BP (Macknick, 2009)). The primary energy equivalent for:

nuclear energy	1 kWh = $(3.6 \div 0.33) = 10.9$ MJ;
hydropower	1 kWh = $(3.6 \div 0.34) = 10.5$ MJ;
renewables	1 kWh = $(3.6 \div 0.34) = 10.5$ MJ;
geothermal heat	1 kWh = $(3.6 \div 0.5) = 7.2$ MJ.

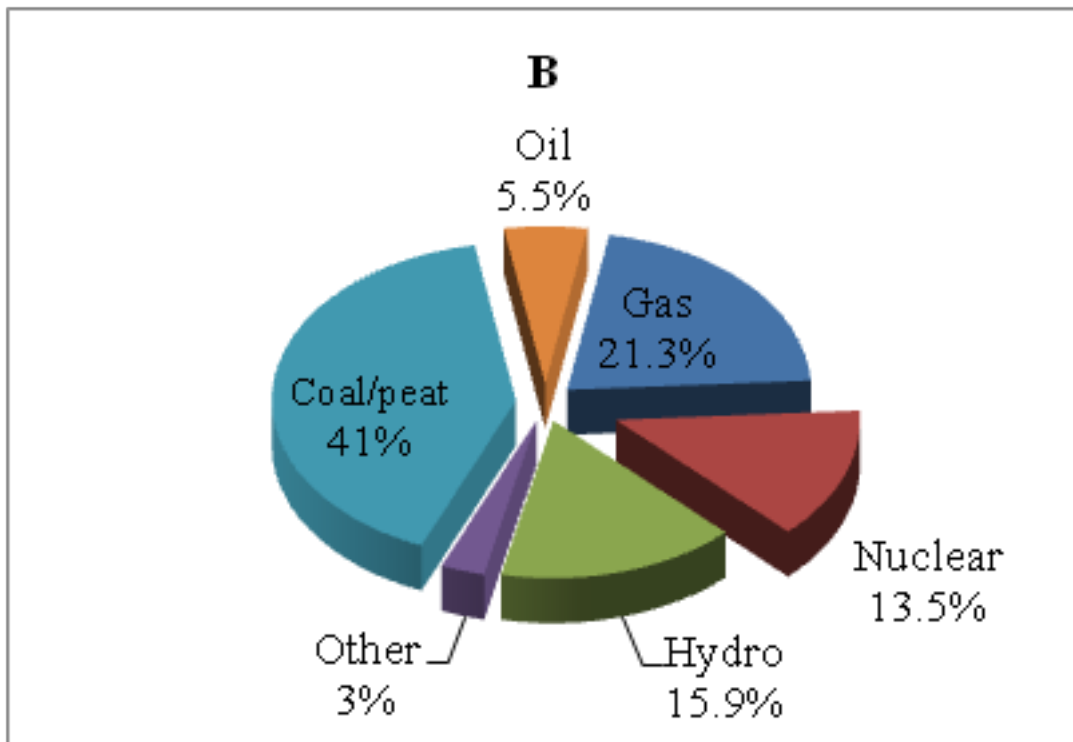


Figure 2: Fuel shares of electricity generation (2018) (TWh)

Created using data from "Key World Energy Statistics 2010", IEA.

According to the IEA data from 2008, global installed capacity of nuclear energy was approximately 370 GW with the United States (101GW), France (63GW), Japan (48GW), Russian Federation (23GW) and Germany (20GW) sharing 70% of total installed capacity (Figure 3). There were 438 nuclear power reactors operating in 31 countries (European Nuclear Society, 2009; IEA, 2008). Another 44 plants in 14 countries were under construction with a total capacity of approximately 39 GW (Figure 4). 83% of regional share of nuclear production is in OECD countries of, followed by former Soviet Union with 9.7% and Asia 5% (excluding Japan and Republic of Korea).

France remains the absolute leader with 77% share of nuclear energy in domestic

⁷ *Ibid.*, p.29.

electricity generation (Figure 7), followed by Ukraine at 47%, Sweden at 43%, Japan at 34% and Republic of Korea at 24%. Other countries that use nuclear energy to provide a significant portion of their electricity (15% or more) include Armenia, Belgium, Bulgaria, Canada, the Czech Republic, Finland, France, Germany, Hungary, Japan, the Republic of Korea, Russia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Ukraine, the United Kingdom, and the United States (World Nuclear Association, 2009). Thus nuclear energy is currently a significantly utilized alternative energy source.

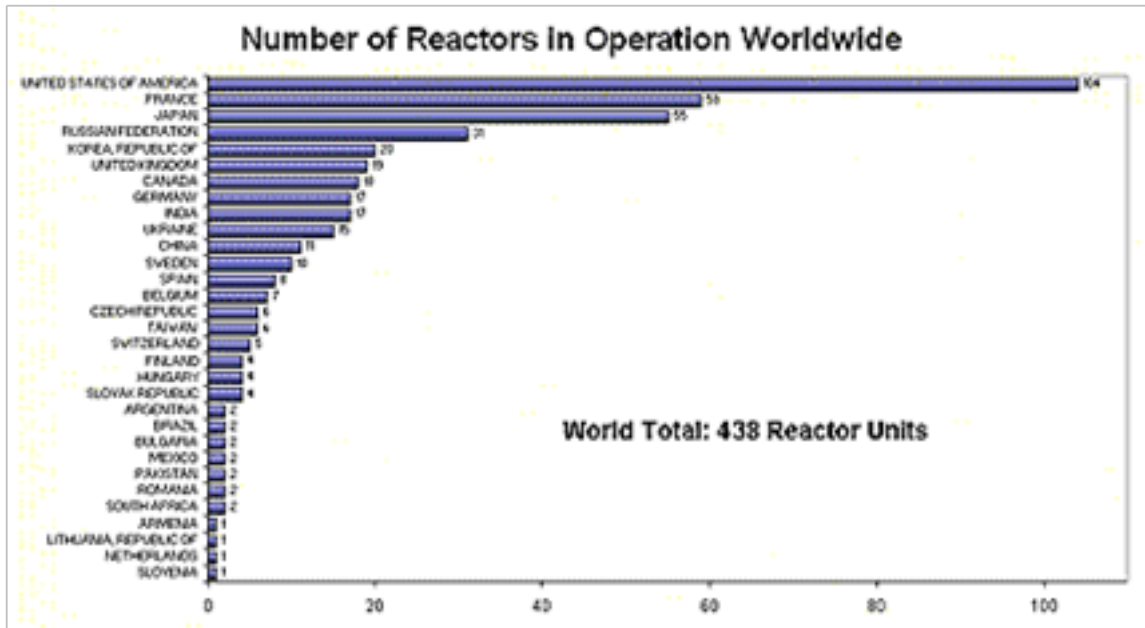


Figure 3: Number of Reactors in Operation, Worldwide, January 2009 (IAEA 2009, modified)

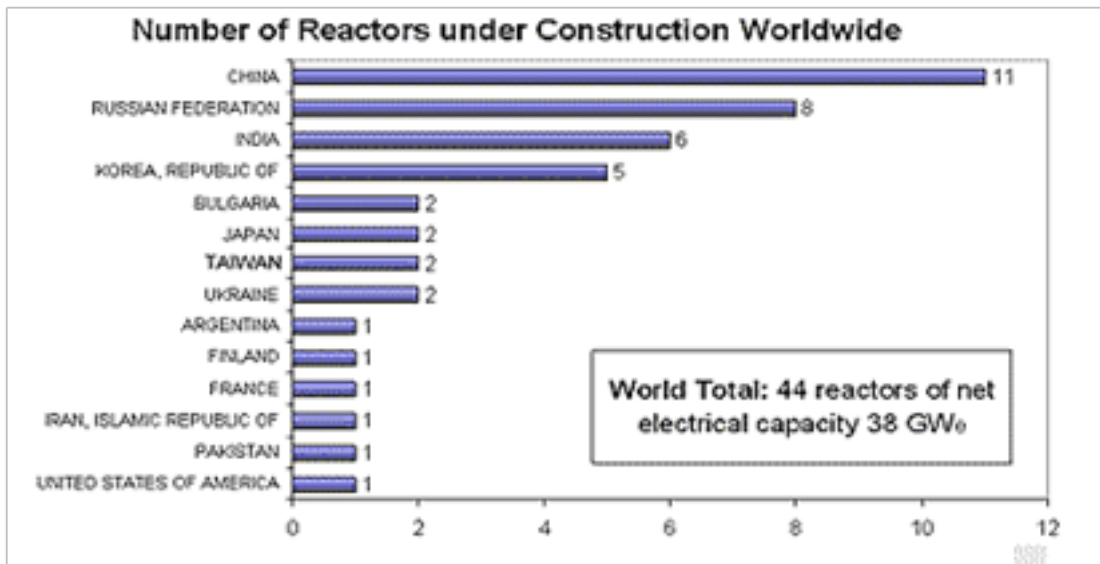


Figure 4: Nuclear Power Plants under Construction, January 2009 (IAEA 2009, modified).

Table 1: Nuclear Power Plants Worldwide, in Operation and under Construction, as of January 2009 (IAEA Nuclear Technology Review 2009).

Country	In Operation		Under Construction	
		Electr. net output MW		Electr. net output MW
Argentina	2	935	1	692
Armenia	1	376	-	-
Belgium	7	5,824	-	-
Brazil	2	1,795	-	-
Bulgaria	2	1,906	2	1,906
Canada	18	12,621	-	-
China	11	8,438	11	10,120
Czech Republic	6	3,619	-	-
Finland	4	2,696	1	1,600
France	59	63,260	1	1,600
Germany	17	20,470	-	-
Hungary	4	1,829	-	-
India	17	3,782	6	2,910
Iran	-	-	1	915
Japan	55	47,587	2	2,191
Korea, Republic	20	17,470	5	5,180
Lithuania	1	1,185	-	-
Mexico	2	1,300	-	-
Netherlands	1	482	-	-
Pakistan	2	425	1	300
Romania	2	1,300	-	-
Russian Federation	31	21,743	8	5,809
Slovakian Republic	4	1,688	-	-
Slovenia	1	666	-	-
South Africa	2	1800	-	-
Spain	8	7,450	-	-
Sweden	10	8,995	-	-
Switzerland	5	3,220	-	-
Taiwan	6	4,921	2	2,600
Ukraine	15	13,107	2	1,900
United Kingdom	19	10,097	-	-
USA	104	100,582	1	1,165
Total	438		44	38,888

As Table 1 shows, developing countries are planning to or are already building many new reactors. Appendix 1 includes descriptions of reactor types on the specific types of reactors in operation, and under construction.

According to an IPCC study (2000), there are more than 400 global and regional scale scenarios for greenhouse gas (GHG) emissions alone that were developed during the

previous three decades. Near and long term studies on energy and related technologies are dated further back than the science of climate change. At the global and regional scale, organizations such as International Energy Agency (IEA), the United States Energy Information Administration, UN Energy Statistics Division and British Petroleum (BP) provide comprehensive databases and reports on energy. Widely used reports include: Energy Balances of Non-OECD Countries, Energy Balances of OECD Countries, International Energy Annual, BP Statistical Review of World Energy, Energy Statistics Yearbook or Energy Statistics Database. However, there are apparent differences and discrepancies in energy data and terminology used (Macknick, 2009); in methodology and metrics in primary energy accounting (UN Statistical Office, 1987; Macknick, 2009; Moomaw W. et al., 2011); in lifecycle assessment and risk analysis (Moomaw W. et al., 2011).

Recent future projections and scenarios include the IEA series on World Energy Outlook for 2010 and 2011, British Petroleum Energy Outlook 2030 (2011), and the International Energy Outlook 2010 with a projection of international energy marked through 2035 conducted by the United States Energy Information Administration. Scenarios, however, are not value free. Descriptive scenarios are evolutionary and open-ended, and explore paths into the future without any preconceived endpoint. Normative (or prescriptive) scenarios are explicitly values-based and teleological, and explore the routes to desired or undesired endpoints (Nakicenovic, et. al. 2000). Furthermore, the energy market is not free from the influence of interest groups and conflict of interests. For example, an assessment of 30 international economic studies on the costs of nuclear energy concluded that a majority of them appear to trim nuclear-cost data (Schrader-Frechette, 2009). After the disaster in Fukushima, the Asia Pacific edition of Fortune magazine (11 April 2011 edition) had the following title "The Future of Nuclear Power: the disaster in Japan is stringing antinuclear sentiment. Can society afford to lose a major source of clean energy?" The answer to this question rather depends on whom to ask. In the field of technology assessment, it is well recognized that technical expertise and analysis are not value free. Biases could be latent and unconscious, as characterized by Slovic (2010), technical experts have following typology: shared material interests, common social characteristics and biases in defining and framing the issue.

The estimation of the World Nuclear Association (WNA, 2010) on future projection of nuclear energy, the WNA Nuclear Century Outlook, is highly optimistic. According to its lowest growth scenario, the projected use of nuclear energy in 2030 will be 602 GWe that is two-fold of installed capacity with the reference year 2008. Whereas, its high growth scenario estimates 1350 GWe by 2030, or almost four-fold the 2008 installed capacity. In contrast, IEA's estimation of the share of nuclear energy is projected to be constant according to its Reference scenario and to increase from 5.7 % in 2008 to 9% in 2030 following the Policy Scenario (WEO, 2010).

1.4. Drivers and Challenges For and Against Nuclear Power

There are various reasons and driving forces behind why countries consider the nuclear energy programme as a part of their energy policy.

1.4.1. Volatility of fossil fuel prices

It is widely accepted that rapid changes in energy prices can cause volatility in local and global economies. In fact, this idea is introduced routinely in microeconomics courses. Anecdotal evidence suggests that many countries are reassessing their energy security policies and contemplate including greater use of nuclear energy in the future because it may be more economically stable than fossil fuels (OECD, 2005; WNA, 2011; IAEA, 2008). Volatility of prices is included on the list of potential drivers in favour of nuclear energy (OECD, 2005; WNA, 2011; IAEA, 2008, IAEA, 2010). However so far, it has had more effect on fossil fuel plant investment rather than on nuclear power (IAEA, 2010).

1.4.2. Energy security

From this perspective, which is understood as the physical availability of supplies to satisfy demand at a price which is affordable for economic and social sustainability (IEA; IAEA, 2005), nuclear energy is seen as one of those options to diversify energy resources and to increase indigenous energy production with an ultimate aim to decrease one's net energy import dependency. This in turn will reduce those risks associated with disruptions of energy resources supply. Heavy reliance on imported energy would involve, first, a risk related to a physical availability of energy sources that can satisfy the demand; second, a type of risk concern price, which should be affordable both in economic and social terms. Giving the multi-dimensional aspect of energy security, the European Union's definition is wider compared to IAEA and includes a third element, that is, political stability/regime in exporting countries.⁸

Driving factors determining country's import dependence are the extent of its indigenous energy reserves, the level of indigenous supply and demand for energy (Bolton, 2010); the development of alternatives such as renewable energy and the efficiency of the energy system in particular of electricity transformation (EEA, 2009).

The net import as a percentage of total primary energy supply is a proxy indicator for energy import dependence (see Table 2). For example, the EU's energy system remains highly dependent on fossil fuels. The EU's dependence on imports of fossil fuels (natural gas, solid fuels and oil) from non-EU countries rose from 47.8% in 2000 (as a share of total gross inland energy consumption) to 54.5 % in 2007 (EEA). Import of uranium, following to the EU's approach on energy security, is regarded to be in preferable environment compared to petroleum products as its main supply comes from geopolitically stable areas.

A short term solution to overcome these risks associated with import dependency is to store the strategic energy resources.⁹ While it is difficult to store natural gas and coal: natural gas storage requires solid investment whereas coal will require a very large volume due to its low energy output, nuclear power plants (NPP) can store fuel for several years and thereby; ensure the stability of its electricity price during that period

8 "Science for Environment Policy": European Commission DG Environment News Alert Service, 18 March 2010. Edited by SCU, The University of the West of England, Bristol.

9 Paragraph 8, Council Directive 2009/119/EC of 14 September 2009.

(IAEA, 2007).

Table 2: Dependence on imports indicator for selected countries

Country	Net Imports	Total primary energy supply (TPES)	Net imports as a share of total primary energy sources (TPES)
	Million tons of oil equivalent		%
Republic of Korea	195.11	226.95	86
P.R. China	210	2 131	9.8
Chinese Taipei	97.45	105.49	92.37
Japan	418.89	495.84	84.48
India	157.89	620.97	25.42
Pakistan	20.21	82.84	24.39
Philippines	18.80	41.07	46
Malaysia	-17.61	72.75	- 24
Mongolia	-0.68	3.15	- 21.58
Singapore	55.85	18.52	301
Thailand	46.24	107.20	43.13
Vietnam	-10.63	59.42	- 18

Source: Created from IEA data, 2008 TPES = Total primary energy supply: production + imports – exports – international marine bunkers – international aviation bunkers +/- stock changes (*Key World Energy Statistics 2010. International Energy Agency, Paris, France*)



Figure 5: Distribution of identified resources (< USD 130/kgU)

Source: *Uranium 2007: Resources, Production and Demand. A Joint Report by the OECD and Nuclear Energy Agency and the International Atomic Energy Agency. OECD Publishing 2008.*

1.4.3. Resource distribution

According to the *OECD/IAEA Red Book Uranium 2007*, the identified resources - a sum of reasonably assured and inferred resources of uranium that can be mined for less than

80 USD per kilogram (<USD 80/kgU) is about 4.4 million tons of uranium metal (tU); and 5.4 million tU that can be mined for < USD 130/kgU. In addition, an estimation of total undiscovered conventional resources is likely to be around 10.5 million tU and then a supply of uranium can satisfy the current demand for up to 100 years (Euratom Annual Report 2008; OECD/IAEA, 2008).

Compared to the fossil fuels, global distribution of the identified resources of uranium is geographically widespread and 93% of total identified resources are shared by 13 countries (Figure 5). From the energy security perspective the geographical diversity and political stability amongst the supply countries is considered as a strong advantage of nuclear energy (Euratom Annual Report 2008).

1.4.4. Growing demand and the price of fossil fuels

According to the IEO2010 Reference case, energy consumption is projected to increase by 49 % from 495 quadrillion Btu in 2007 to 739 quadrillion Btu in 2035. For the first time, non-OECD countries exceeded the amount of energy use of OECD (see Figure 6). China and India are estimated to share 54% of increase in global primary energy demand (WEO, 2010). It is projected that the fossil fuels (coal, gas and oil) will remain to dominate the energy market sharing the 80% from the total primary energy supply for the Reference Scenario 2030 (WEO, 2010). The net growth of demand for oil primarily comes from non-OECD reaching to 99 million barrels per day in 2035 which is higher than in 2009 by 15 mb/d and a half of this demand from China alone (WEO, 2010).

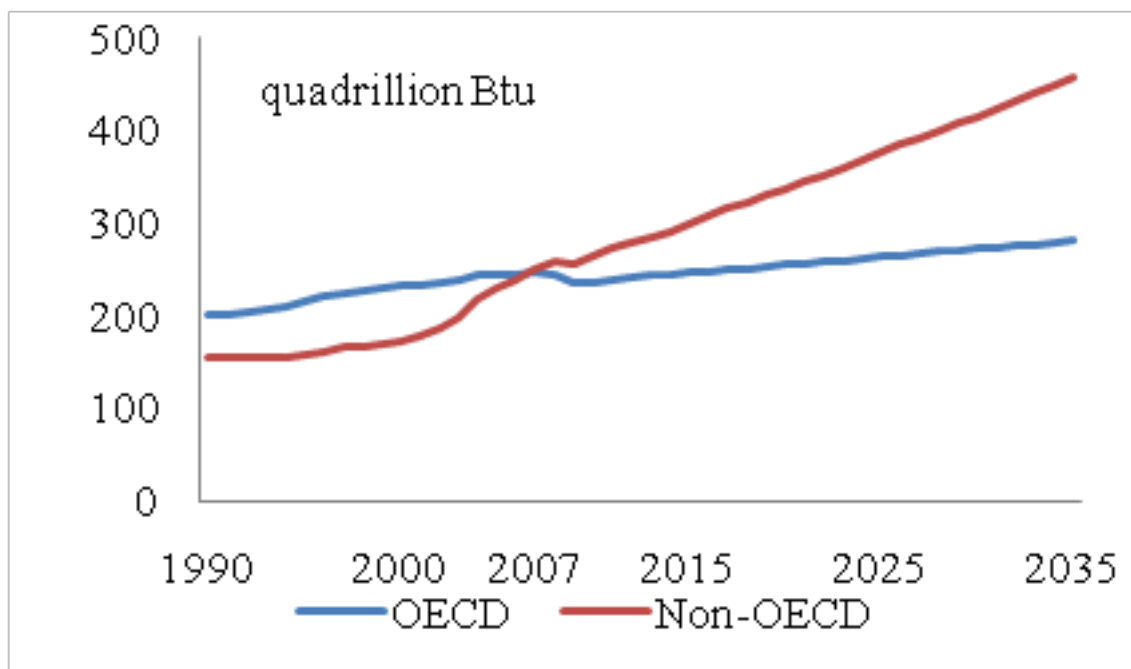


Figure 6: World energy consumption: OECD and Non-OECD, 1990-2035

Source: EIA, 2010.

Based on these projections, increasing demand for primary energy sources and electricity, some sources like WNA's *The Nuclear Renaissance, World Energy Outlook*

(WNA, 2010) and International Energy Outlook 2010, project a higher price for fossil fuels. However, there is no consensus when it concerns about its effect in energy sector.

According to the World Nuclear Association (WNA, 2011) “increasing fossil fuel prices have greatly improved the economics of nuclear power for electricity”, and that “nuclear energy is most cost-effective of the available base-load technologies, at least when natural gas prices are high”.¹⁰ In contrast, EIA suggests that “projected high price for oil and concern about the environmental impacts of fossil fuel use and strong government incentives for increasing the use of renewable energy in many countries around the world, improve the prospects for renewable energy sources worldwide in the outlook” (IEO, 2010). IEA has the similar conclusion, that natural gas “is the only fossil fuel for which demand is higher in 2035 than in 2008 for all scenarios” and that it is “set to play the central role in meeting the world’s energy needs” (WEO, 2010). Nevertheless, as there is little consensus on correlation between the high price for fossil fuel and nuclear energy.

1.4.5. Human development

There are social and developmental dimensions as well. Different metrics such as Indicators for Sustainable Energy Development (IAEA/UNDESA, 2001), Human Development Index (UNDP, 2010) or Energy Development Index (IEA, 2010) indicate the correlation between the energy (electricity) use and life expectancy and literacy (Alam *et al.*, 2001; Saghir, 2005); energy use and human well-being (Alan, 2000; UNDP Human Development Report for 2007-2008); indoor use of biomass and the premature annual deaths from household air pollution (WHO, 2005; OECD/IEA, 2010). According to the WHO, indoor air pollution causes the death of 1.6 million people - that’s one death every 20 seconds. The use of polluting fuels thus poses a major burden on the health of poor families in developing countries, especially on women and children as in most cases women spend from 3 to 7 hours per day near the stove.

The is current inequality in access to electricity, with 1.4 billion people lacking access globally,¹¹ and traditional biomass is used by 2.7 billion people. This is unlikely to decrease in long term; and most of them will be in India and other developing nations in Asia (WEO, 2010). India is expected to account 18% of rise of global energy demand and thereby, become the second largest contributor in rising demands for energy.

1.4.6. Climate change

There are benefits of nuclear energy from the climate change perspective as it has a high energy density. These advantages, however, do not translate into the formula – a greater consideration of nuclear energy because it helps to reduce the emission of greenhouse gases (GHG). First, as discussed above under the heading “Growing demand and the price of fossil fuels”, there is no evidence to support this correlation. Second, nuclear energy is excluded from the Clean Development Mechanism (CDM)

10 World Nuclear Association, *The Nuclear Renaissance*, updated 14 August 2011. <http://www.world-nuclear.org/info/inf104.html>

11 Refer to Moss *et al.*, (2011).

which is intended to assist industrialised countries to offset their GHG reduction targets under the Article 3 paragraph 1 of Kyoto Protocol by funding projects in developing countries that lead to emission reduction.

At the time of the Sixth Conference Parties (COP-6), The Hague 2000 and Bonn 2001, the emission reduction mechanisms and the regime of 'carbon trade' was in the agenda. Particular issues of debate, among others, were whether nuclear energy should be counted for credits of emission reduction to meet the targets set in the Article 3 of the Kyoto Protocol. Least developing countries concerned that CDM credits may divert "nuclear mega-projects in countries like China, India and South Korea, further reducing the resources available for sustainable projects in non-nuclear developing countries".¹² The majority of the EU, New Zealand, Norway, Austria, Honduras, Costa Rica, Greece, Indonesia and Tuvalu were opposed to including nuclear energy in the CDM. Exceptions include UK, France, China and India, while IAEA "urged Parties to consider nuclear energy in the context of climate change, stating that the concerns about safety and possible proliferation of weapons are not based on climate concerns".¹³ And it was decided that "Parties included in Annex I are to refrain from using certified emission reductions generated from nuclear facilities to meet their commitments under Article 3, paragraph 1".¹⁴

In fact, this debate over the permission of nuclear energy to be included in CDM is driven by different approaches to sustainability. Japan argued that it is the host country (developing country) to decide what is sustainable. Others were in favour to list certain technologies and that would be considered sustainable. In case of nuclear energy, the prevailing voices were that it is not a clean and sustainable technology considering the full cycle of nuclear fuel– uranium mining, processing, fabrication and waste disposal (OECD, 2002).

1.4.7. Proliferation

Civilian nuclear technology can be used for military purposes, and increased proliferation concerns in recent international events focus attention on this dual-use aspect of nuclear technology. Recent disagreements between intergovernmental organizations, such as the International Atomic Energy Agency (IAEA) and the UN Security Council (Sagan, 2006; Hagel, 2008; Crail, 2008; Ikenberry, 2007), with particular states over safeguards highlight these concerns. This issue will be discussed in detail in section 5.3.

1.4.8. Emerging and potential nuclear energy countries

In summary we can see that nuclear energy production plays an important share in electricity production in many countries (Figure 7). An increasing number of countries without previous nuclear energy experience are showing interest in developing

12 The Clean Development Mechanism: An instrument for sustainable development or a new nuclear subsidy? Nuclear Information and Resource Service.

13 Earth Negotiations Bulletin, 2000. Vol. 12. No 163..

14 Decision 17/CP.7, FCCC/CP/2001/13/Add.2.

nuclear energy capacity for various reasons. Twenty-five countries have shown interest in building at least one large nuclear reactor by 2030 (Sokolski, 2009). This will cause a different international relations picture with regards to nuclear technology, including nuclear fuel supply, in the future. As Figure 4 and Table 1 show, developing countries are planning to or are already building many new reactors. Appendix 1 includes descriptions of reactor types and tables on the types of reactors in operation, and under construction.

However, following Fukushima some countries such as Germany, a current user, and Thailand, a prospective user, have stated that they will not use nuclear energy for electricity production. While nuclear plants have become far less susceptible to problems which can cause radiation leaks, the Fukushima incident demonstrates that this issue is still very much a factor in considering the future of nuclear energy and by extension, the ethics of nuclear energy.

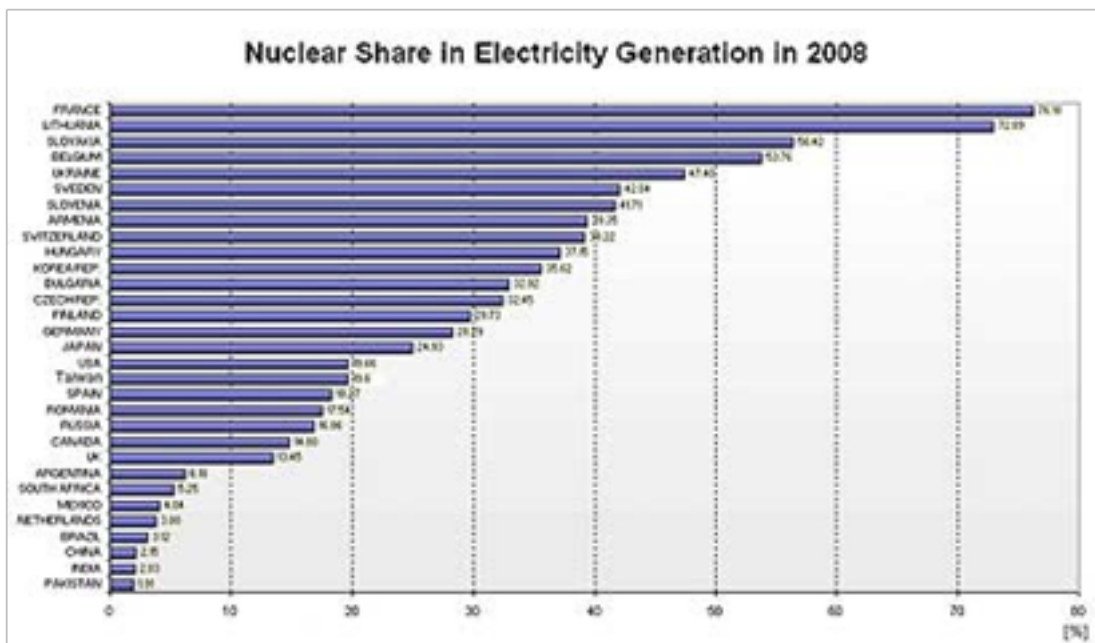


Figure 7: Nuclear Share in Electricity Generation, 2008 (IAEA 2009, modified)

2. The Ethics of Nuclear Energy Technology

Nuclear energy technology involves the application of nuclear science to generate power, namely electrical power, from nuclear power plants. It also involves the nuclear fuel cycle, which involves fuel being mined, processed, and used at the plant and being eventually expended as spent waste. The ethics concerning such nuclear energy technologies is discussed in this section.

2.1 Nuclear Science and Nuclear Power Plants (NPPs)

Nuclear energy can be harnessed from one of two types of nuclear reactions, fusion and fission. In nuclear fusion, atoms are fused or combined to form different atoms. This reaction powers stars such as the sun. It is currently uneconomical as a source of electricity, although it has been harnessed in thermonuclear weapons. Current projects, such as the ITER fusion research collaboration (ITER, 2009), are working on developing nuclear fusion as an electricity source. While estimates vary, this technology is several decades away from commercial use (see for example Sharp, 2007). Moreover, even if and when it arrives for commercial electricity production, it may be expensive (Nuttall, 2008). However, fusion has the potential to generate larger amounts of electricity at lower prices and with minimal impact to the environment. In addition, the source of fuel, tritium, is extremely abundant and inexpensive; very little radioactive waste would be produced; and it will not use uranium nor plutonium which can be diverted for weapons manufacture unlike nuclear fission (Nuttall, 2008).

The second type of nuclear reaction is fission. In nuclear fission, atoms are split and energy is generated. This form of energy has been utilized in both electricity production and weapons. It is the focus in the remainder of this report.

The nuclear power plants (NPP) used today use fission to generate electricity from nuclear energy. More specifically, a nuclear reactor, housed within the plant, converts the heat energy generated from nuclear fission to electricity. Appendix 1 includes descriptions of reactor types and tables on the types of reactors in operation and under construction.

Nuclear fuel is formed into pellets that are stacked inside fuel rods (WNA, 2009). Nuclear reactors can contain tens of thousands of such fuel rods. The heat is captured by moderators, which also cool the fuel rods and prevent them from melting (WNA, 2009). The most common moderator is pressurized water, because it has a high capacity to absorb heat. The pressurized water, which travels in a primary loop, moves through a heat exchanger, transmits the heat energy to a secondary water loop. The water in the secondary loop is then turned to steam, which drives a turbine in a heat engine. The turbine generates electromagnetic energy, which is converted to electricity. After the heat is converted to energy, the coolant must be cooled through heat exchanges which retain the reactor coolant inside a closed system, while exchanging heat with water from another source, like the ocean, which can then be seen as the steam is evaporating from the large cooling towers of NPPs, similar to the heat exchangers from other thermal power plants, including some coal burning power plants.

Control rods are used to regulate the amount of energy produced by the reactor. Usually, the more the control rods are inserted into the core, the more the fission reaction is inhibited as they absorb neutrons. They are also designed to be able to stop the nuclear reaction in the reactor in an emergency. One design has them hanging over the cores by a mechanism such as magnetic clamps such that when an emergency occurs, the magnets automatically turn off and the control rods fall into the core, stopping the nuclear reaction as the neutrons are absorbed (Online Ethics Center, 2009). There is still a need to remove the heat from the reactor core by a cooling system.¹⁵

The environmental benefits of nuclear energy can be seen clearly in France. In the 1980s, because of concerns over imported oil, France more than tripled its nuclear energy production. During the same period, total pollution from the French electric power system dropped by 80-90% (Nuclear Energy Institute, 2009). Thus NPPs have low GHG emissions under normal operations, mainly associated with the costs of mining of uranium.

Nuclear fusion and fission have not given rise to any significant intrinsic ethical debate, because atoms themselves are not moral agents. This is in contrast to fields such as biotechnology, biology and the life sciences, where complex ethical issues involving animal use, or genetic modification of DNA of plants and bacteria to produce biofuels, arise.

However, when nuclear science is applied as an energy technology, a number of ethical concerns are generated. Most of these stem from the potentially dangerous effects of radiation, the reactor technology used to harness nuclear energy, potential diversion for military use, the cost of such technology, and international control of nuclear technology.

2.2 Nuclear Radiation

The risks of radiation from nuclear technology are difficult to assess. While general agreement exists on the dangerous effects of high-dose radiation, effects of radiation at low-dosages (less than 100 millisieverts per year) also appear to cause harm (UNSCEAR, 2010). One hypothesis, the linear no-threshold (LNT) hypothesis, posits that harmful radiation effects are linearly proportional to the radiation dose (IAEA, 2007). Competing hypotheses posit that radiation is harmless below certain thresholds but harmful above them. Yet another hypothesis, called radiation hormesis, posits that low radiation doses are actually beneficial below a certain threshold and harmful above it (Kaiser, 2003). Thus, it is difficult for policy-makers and the general public to understand radiation safety options when even experts cannot agree on low-dose radiation effects.

The International Council for Radiation Protection (ICRP) is a guidance setting authority for radiation protection, comprised of biologists, physicians, and physicists, among others ICRP (2009).¹⁶ The ICRP proposes “as low as reasonably achievable” (ALARA) as

¹⁵ See chapter 3 on Fukushima and Chernobyl meltdowns.

¹⁶ ICRP. 2009. http://www.icrp.org/docs/2005_recs_CONSULTATION_Draft1a.pdf

being a goal for risk assessment and management.¹⁷ However, the precise definition is unclear, and varied legal and ethical interpretations can be applied. A common understanding on ALARA or safety level of low radiation doses may therefore assist policy-makers, the general public, and even workers in the nuclear industry, to understand and formulate policy options.

2.3 Accidents Involving Nuclear Power Plants (NPPs)

Nuclear plants are considered an ethical issue because of this possibility of a nuclear accident. A nuclear meltdown can occur if fission creates too much energy and overheats, causing damage to the surrounding structures and releasing radiation into the environment. It can also occur if the structures surrounding the nuclear reactor themselves suffer a malfunction, allowing radiation leaks. Finally, it can occur if cooling systems, such as the pressurized water moderator, malfunctions, damaging the structures surrounding the nuclear reactor, and release radiation into the environment. Accidents at Three-Mile Island in the United States (1979), Chernobyl in Ukraine (1986), and Fukushima in Japan (2011) have prompted the public to raise serious questions about nuclear safety (OECD, 2005).

However, when we consider the types of risk inherent in most energy options it may be difficult to argue that nuclear energy should be absolutely prohibited simply because accidents can occur. Nuclear energy can be considered as a safe source of electricity under normal operating conditions with sufficient control systems. As a comparison, several thousand persons die in coal mine accidents each year, and hundreds die in the oil and gas industry; not to mention the added complications of health to miners and the public in general, and environmental effects.

On the other hand, it is equally difficult to argue that such accidents should be downplayed and are “unlikely”. Utilitarianism may consider a simple multiplication product of the magnitude of the harm multiplied by the probability of its occurrence. In the case of nuclear meltdowns, the magnitude of the harm can be enormous. While Three-Mile Island did not produce any direct recorded deaths from radiation, the indirect health and environmental damage was inconclusive. The accident in fact demonstrated the importance of safety systems. Even though half the reactor core melted, the radionuclides that were released mostly plated out on the inside of the plant or dissolved in the condensing steam. The containment building housing the reactor also prevented any significant release of radioactivity. The reactor’s other protection systems also came into action.

In 1966, A US Fermi-1 prototype fast breeder reactor (FBR), near Detroit was closed down due to a blockage in coolant flow and the consequent melt down of some fuel. However, no radiation was released and no injuries were reported (WNA Encyclopedia of Earth, 2010).

The nuclear disaster in Chernobyl in April 1986 (WNA, 2010), however, was the first major event in recent times that actually led to radiation-induced fatalities. Many confirmed

¹⁷ ICRP. 2005. http://www.icrp.org/docs/2005_recs_CONSULTATION_Draft1a.pdf

deaths due to radiation burns or people developing cancer after the accident have been reported. 28 people died within weeks due to radiation exposure, and it caused radiation sickness in 200-300 fire fighters and staff and contaminated large areas of Belarus, Russia and beyond. It is estimated that about 5% of the radioactive material from the Chernobyl-4 reactor core was released from the plant.¹⁸

Until Fukushima in 2011, Chernobyl and Three-Mile Island were the only major accidents of a nuclear meltdown. The fact that Fukushima disaster occurred despite comprehensive safety systems and multiple redundant safety systems, and inherent and passive safety systems, has significant implications for nuclear safety and is considered in chapter 3. Although Fukushima nuclear accident was triggered by a major earthquake and tsunami that led to loss of power for the cooling systems, resulting in meltdowns in at least two reactors, the NPP had been designed with the recurrent risk of earthquake and tsunami in that region of Japan in mind. The risk preparations were thus proven to be insufficient, as admitted by the Japanese government (Japan, 2011) with a number of implications for many other NPPs built close to geological faultlines.

Many documents considering ethical issues and guidelines exist, such as those from the World Association of Nuclear Operators (WANO) and the International Atomic Energy Agency (IAEA). The IAEA Nuclear Security Guidelines published in 2006, provides eleven guiding principles and includes guidance on design, testing qualifying and purchasing of radiation monitoring equipment to all its Member States. It includes tools and procedures for nuclear forensic investigations, identification of radioactive sources and devices and so on (IAEA: Nuclear Safety and Security). However, perhaps more comprehensive, integrated, and measurable safety cultures can be implemented through mechanisms ranging from safety guidelines to employee performance appraisals (WNA, 2010).

Table 3 shows the international nuclear event scale (INES) and some nuclear power related accidents and their associated impacts.¹⁹ The data was collated by the IAEA and OECD to communicate and standardize the reporting of nuclear accidents to the public (European Nuclear Society; WNA Encyclopedia of Earth, 2010) in the aftermath of the Chernobyl accident.

18 The Chernobyl (Ukraine) nuclear power plant disaster in April 1986 was the result of a flawed RBMK-1000 reactor, which was a Soviet design. It was a boiling water reactor using uranium dioxide (enriched with 2% ²³⁵U). A series of operator actions including the disabling of auto shut down mechanisms prior to an attempted testing of the reactor turbines led to a dramatic power surge. This caused the reactor to become extremely unstable, resulting in a violent steam explosion and release of fission products into the atmosphere. While most of the released material was deposited nearby as dust and debris, the lighter material was carried by wind over Belarus, Russia, Scandinavia and other parts of Europe. Radiation doses on the first day were estimated in the range of 20,000 millisieverts (mSv), causing 28 deaths - 6 of which were firemen. The initial radiation exposure in contaminated areas was due to short-lived (half-life of 8 days) radioactive iodine (¹³¹I) and later cesium (¹³⁷Cs, half-life of 30 years) which are the main hazards. Further discussion is in chapter 3.

19 International Nuclear and Radiological Event Scale; can be found at <http://www.iaea.org/Publications/Factsheets/English/ines.pdf>

Table 3: International Nuclear and Radiological Event Scale

Level, Descriptor	Off-Site Impact	On-Site Impact	Defence-in-Depth Degradation*	Examples
7 - Major Accident	Major Release: Widespread health and environmental effects			Chernobyl, Ukraine, 1986 (fuel meltdown and fire) Fukushima, Japan 2011 (fuel meltdowns and explosions)
6 - Serious Accident	Significant Release: Full implementation of local emergency plans			Mayak at Ozersk, Russia, 1957 (reprocessing plant criticality)
5 - Accident with Off-Site Risks	Limited Release: Partial implementation of local emergency plans	Severe damage to reactor core or to radiological barriers		Windscale, UK, 1957 (military). Three Mile Island, USA, 1979 (fuel melting).
4 - Accident Mainly in Installation	Minor Release: Public exposure of the order of prescribed limits	Significant damage to reactor core or to radiological barriers, worker fatality		Saint-Laurent, France, 1980 (fuel rupture in reactor). Tokai-mura, Japan, 1999 (criticality in fuel plant for an experimental reactor).
3 - Serious Incident	Very Small Release: Public exposure at a fraction of prescribed limits	Major contamination, acute health effects to a worker	Near Accident. No safety layers remaining	Vandellós, Spain, 1989 (turbine fire, no radioactive contamination). Davis-Besse, USA, 2002 (severe corrosion). Paks, Hungary, 2003 (fuel damage)
2 - Incident	Nil	Significant spread of contamination, overexposure of worker	Incidents with significant failures in safety provisions	
1 - Anomaly	Nil	Nil	Anomaly beyond the authorized operating regime	
0	Nil	Nil	No safety significance	
Below Scale ¹	Nil	Nil	No safety relevance	

Defence-in-depth covers events that did not directly impact people or environment, but for which the range of measures put in place did not function as intended.

¹Denotes events without safety significance- called deviations and are classified "Below Scale" or "Level 0" Source: www-news.iaea.org

The INES scale runs from "0" (no safety significance) to "7" (major accident) and was

initially used to classify events occurring at NPPs only.²⁰

A second issue arising from nuclear plants is low-level radiation leaks into the environment. There have been studies showing that there are such possible leaks, but the overall results have been inconclusive. For instance, a recent German study found that children under the age of five living less than five kilometres from nuclear plant exhaust stacks had twice the risk for contracting leukaemia as those residing more than five kilometres (Nussbaum, 2009). However, such studies are contradictory to the conclusions of other studies, as the report admits (Nussbaum, 2009). The scientific issue may revolve around study methodologies and what “statistically significant” really means. As to the scientific cause, this may be from the water being used to drive the turbines in the secondary loop containing low levels of radiation, which are carried away into the environment, or in the waste produced by the plant, which may inadvertently be leaked into the surroundings. These are also subject to an ethical calculation, but the information on magnitudes and probabilities are inconclusive. Nuclear fallout from accidents decades ago may have also resulted in low-level radiation, although this would be at a reduced level today. For instance, ⁹⁰Sr, which is considered hazardous, was dispersed from Chernobyl (Chernobyl Forum, 2006; EPA, 2009) and Fukushima (Japan, 2011).

2.4 Nuclear Fuel and Mining

2.4.1. Uranium as a fuel

Uranium, the most commonly used nuclear fuel, exists as one of several isotopes in nature. The nuclear fuel extracted from nature is ²³⁵U, which is present in small percentages in uranium ore. Most of the uranium in the ore is found as ²³⁸U, which will not undergo fission with current technology.

It is useful to speak of the nuclear fuel cycle, which traces the steps of nuclear fuel from its inception to its eventual destruction. Nuclear experts often divide the nuclear fuel cycle into two parts, the “front end” and the “back end”. Before it can be used in a nuclear reactor, the ²³⁵U is mined, milled, converted, enriched, and fabricated into fuel assemblies. Collectively, these steps comprise the front end of the nuclear fuel cycle (WNA, 2009). The fuel undergoes fission in a nuclear reactor, produces energy, which is converted to electricity, and becomes “spent fuel”. Spent fuel enters the back end of the nuclear fuel cycle (WNA, 2009). The back end comprises the steps of temporary storage, reprocessing, and recycling, and waste disposal (WNA, 2009).

²³⁵U is found within ore deposits around the world. More than half of the world's uranium production is derived from mines in Canada, Australia, and Kazakhstan (Tradetech, 2009). The uranium ore is mined from the ground using conventional

20 The INES was subsequently extended to rate events at any nuclear facility and during transport of radioactive material thereby covering incidents of radiation exposure to people involved. Since 2008, the INES has also been extended to cover any event associated with the transport, storage and use of radio-active material and radiation sources from those occurring at nuclear facilities (European Nuclear Society). More information on nuclear events from radiation sources, transport and other nuclear facility related accidents can be found in the IAEA publications (www.iaea.org)

mining techniques: open-pit, underground, *in-situ*, and as a by-product of mining other minerals such as phosphates (Tradetech, 2009). As such, uranium extraction is subject to all of the ethical issues that conventional mining entails, as it can inflict harm on human health and the environment.

2.4.2. Detrimental effects of mining

Although different mining techniques produce different effects, there are three general categories of direct detrimental effects. The first is physical, and includes unstable waste rock piles, old buildings, open mine workings, pits and tunnels, derelict buildings and machines, and water filled voids (IAEA, 2008). These are common to mining of most ores.

2.4.3. Chemical pollution

The second is chemical, and includes ponds of contaminated water, acid drainage from reactive waste, old processing chemicals and residues (IAEA, 2008). Physical and chemical hazards can represent significant human health and environmental problems to the local community and surrounding areas, especially if they are not addressed immediately. Chemical problems, in particular, can cause large ecological and economic damage if not properly treated and/or remediated.

2.4.4 Radiological concerns

A third detrimental effect of uranium mining, which is not shared by conventional mining, is radiological, and includes uranium mill tailings, unprocessed uranium-bearing ore, scale and sludge in old plants, contaminated scrap metal, and release of uranium dust and radon gas into the environment (IAEA, 2008; UNSCEAR, 1982). Some radiological hazards can be addressed as with physical and chemical problems, but if they are not addressed quickly, they can cause economic and ecological damage to the local community and surrounding areas. Other radiological hazards require specialized methods of remediation and treatment.

One widely documented study showed the radiological effects of uranium mining on human health. During the 1950s, many Navajo uranium miners in the U.S. later developed cancer due to radon gas exposure (Brugge, 2002; Miller, 2007). While former miners have been partially compensated, there have been reports that hundreds of abandoned mines have not been cleaned up and present environmental and health risks in many communities.²¹ There have been other instances where radioactive contamination has affected uranium miners. For instance, Areva, a French state-owned nuclear power company, allegedly did not inform its affected mine workers in Niger about the health risks of uranium mining despite detrimental health effects (Public Eye, 2008). Areva is a company contracted to clean up contaminated material in Japan after Fukushima.

21 Los Angeles Times. 2006. *A peril that dwelt among the Navajos*. <http://www.latimes.com/news/nationworld/nation/la-na-navajo19nov19,0,1645689.story>.

Another case is the condition of people and some ethnic tribes in the uranium mining regions of India, which is explored in detail in subsection 2.4.5. While there have been contradictory reports about the health conditions of the local populations who live close to the uranium mines; alleged incidences of cancer, miscarriages and still-births have been widely reported due to radiation contamination of potable water. Radiological contamination from uranium mining processes is an area of serious concern from an ethical stand point as well as protection of the well-being of people and environment.

2.4.5. Assessment of Impacts on Human Health and the Environment in India

This case study will examine the broader impacts on environmental, physical and mental health. The first uranium mine in India was opened at Jadugoda, Jharkhand state, India, where uranium is being mined since the establishment of the Uranium Corporation India Limited (UCIL) in 1967. At present, uranium is extracted from Jadugoda, Bhatin, Turmadih, Bagjata, Narwapahar and Banduhurang mines by the UCIL. However, the presence of uranium in this area was known since 1937 and after independence of India in 1947, a team of Atomic Mineral Division, Government of India made a thorough survey of this area which is known as the Singbhum Thrust Belt and found a 160 km long stretch of uranium deposition. Extraction in Bhatin mines started in 1986, Turmadih in 2003, Banduhurong in 2007, Bagjata in 2008, and very recently in Narwapahar mines. The ore from the mines is taken to a processing plant at Jadugoda, where at the final stage concentrated uranium oxide (U_3O_8) at about 74 % purity and popularly known as 'yellow cake' is produced. This is then transported to a Nuclear Fuel Complex for further purification. Tailings from Mosaboni and Rakha copper mines located near the uranium mines also have low concentrations of uranium as an impurity, and the radioactive element is recovered from these tailings as well. Another processing mill has also been established at Turmadih to process the ore from Turmadih and Banduhurong mines. Another mine at Mohuldih, which is 3 km west of Turmadih mine, is now under construction.

Some other areas in Jharkhand and Madhya Pradesh, the most noteworthy deposits of uranium have been found in the West Khasi Hills district of Meghalaya, in Domiasiat and Wakhyn areas and in the Nalgonda district of Andhra Pradesh. The discovery of uranium in West Khasi Hills is the first instance of its presence in a sedimentary basin at a shallow depth of about 45 m. UCIL is, therefore, trying to set up projects at Kyelleng-Pyndengsohiong, Mawthabah, in Meghalaya; and Tummalapalle and Lambapur in Andhra Pradesh.

The production of uranium in India in 2007 was 229 tonnes. The proposed mine at Tummalapalle in Andhra Pradesh is projected to be able to provide more than 170,000 tonnes of uranium, making it the largest uranium mine in the world. This has obvious implications for energy security.

Issues of Concern at Jadugoda

Land Alienation: Sonowal and Jojo (2003) have made a detailed analysis of the issues at the Jadugoda uranium mines. One contentious issue concerns the mine tailings.

The ore at the Jadugoda, Bhatin and Norwapahar underground mines are fed to the processing plant at Jadugoda for further refining to the yellow cake stage. The ore having about 0.06 % uranium is crushed to a powder form and then chemically treated to separate the uranium-enriched fraction. The remaining part of the ore is called tailings and is the waste generated during the mining-milling process. After treating with lime, the coarse fraction of this waste is used to fill the mined tunnels, while the fine fraction in the form of slurry is stored in the tailing ponds. Two such tailing ponds have already been filled with the third one nearing saturation. The UCIL is planning to take up a fourth one, which will displace one entire tribal village having 200 families and fertile agricultural land. This kind of land alienation has led to unrest among the local residents and generated a resistance in the public mind to uranium mining. Jadugoda uranium mine, plant, staff quarters and other facilities were established on tribal land by acquiring about 2000 acres of land and displacing 5 villages mostly inhabited by tribal persons.

There are persistent complaints among the affected people of not receiving adequate compensation or rehabilitation. Many families are now forced to live as squatters by the side of railway tracks and highways. People in the area are therefore opposed to any further land acquisition for the purpose of mining. These sentiments are also being shared by the inhabitants of Bhatin and Norwapahar mine areas. This in fact is the dominant feeling among the tribals of Jharkhand regarding mines in general. According to Areeparampil (1996), the Singbhum area in Jharkhand, where the uranium mines are located, comprises the mining heartland of India, with coal, copper, iron, limestone and other minerals are mined and new mines are regularly being opened up. A long-standing grievance of the displaced tribals is about the inadequate compensation and rehabilitation package that they have been receiving from the mining companies. The other issues include lowering of the groundwater table due to heavy withdrawal by the mining companies and pollution of water sources by effluents from mines and industries.

Health Effects: Besides land alienation and displacement, health hazards from uranium mining and its impact on the environment also are important issues. The anti-uranium mining group have cited the alleged health effects such as high frequencies of cancer, premature deaths of labourers, miscarriages, sterility, deformities, high infant mortality and others at Jadugoda.

An award-winning documentary "Buddha weeps in Jadugoda" was made that speaks of gross negligence, arrogance and apathy of UCIL authorities. The film shows that the tailing ponds are not fenced in, as a result of which the unaware villagers graze their cattle in that area; children often play with scraps from these areas; leaking barrels spill waste; uranium ore is transported in open trucks and workers in the mine lack protective gear. The UCIL representatives interviewed dismiss these allegations. This film was screened at the anti-nuclear meetings in Meghalaya and resulted in generating grave apprehensions in public mind. This was further strengthened by the visit of some NGO representatives and youth leaders from Meghalaya to Jadugoda and they reported that they came across several cases of deformities caused by radiation at Jadugoda (Karlsson, 2009).

Sonowal and Jojo (2003) reports that a survey conducted by the Jharkhandis' Organization Against Radiation (JOAR) found a high rate of disruption of menstrual cycle, miscarriages and still births and various problems in conception among the women of Jadugoda.

Indian Doctors for Peace and Development (IDPD) conducted a descriptive cross-sectional study on indigenous people mostly belonging to the Santal, Munda and Ho tribes living in five revenue villages near uranium mines, tailing ponds and an ore processing plant run by UCIL in the Jadugoda area. A total of 2118 households in these five villages were included in the study along with 14 reference villages having similar socio-economic status and ethnic composition, but not affected by uranium mining or processing. A structured questionnaire and focus group discussion were used to conduct the survey and glean information from the households by both male and female interviewers. The study revealed that 4.5% of mothers from the affected area gave birth to deformed children against 2.5% from reference villages, with the differences significant at $p < 0.05$ and an odds ratio of 1.84.

A similar study from New Mexico also reported a ratio of 1.83. Further, primary sterility among the couples was also high as compared to the reference villages (9.6 and 6.3%, respectively; $p < 0.05$); and a possible increase in prevalence of cancer (2.87 vs 1.89% in study and reference villages, respectively).²² It was also reported that during a flash flood in 2008, wastes from the tailing ponds spilled over and entered into the ponds, wells and agricultural fields of nearby villages. There were a few incidences of tailings pipeline bursting to release wastes that contaminated the homes of villagers.²³ Among the studies published in peer-reviewed scientific journals, however, only Ghosh et al. (2010) recorded high level of alpha radioactivity in the water of Subarnarekha river near the mining sites that decreased in sites farther away. On the contrary, studies conducted by the scientists of the Environmental Assessment Division of Bhabha Atomic Research Centre, India, and the Indian School of Mines, Dhanbad, India, did not find any cause of concern due to radiation exposure. For example, Tripathi et al. (2008) found the radioactive Radon at local background levels at the boundaries of the tailings ponds; uranium and radium levels in groundwater were also very similar to the regional average, indicating absence of groundwater contamination. Tripathi et al. (2010) also found the radiation dose from all sources to the people in the villages around the mining complex to be within the permissible levels. Intake of radionuclides from vegetables was found to be much below the ICRP recommendations. The total cancer risk due to the consumption of vegetables was also found to be very low (Giri et al., 2010). No significant groundwater contamination by radionuclides was detected around the mining sites of Bagjata and Banduhurang, Jharkhand, India (Giri et al., 2011).

Public Resistance to Uranium Mining

Andhra Pradesh: It has been reported that more than 50 % of the people present in a public hearing at Seripalle, Nalgonda district, in 2005, were opposed to the mining

22 <http://www.pragoti.in/node/2432>

23 <http://www.wise-uranium.org/umopjdg.html>

project at Lambapur and Peddagattu. The local Lambada tribe was very much opposed to the environmental disturbance and interruptions in their traditional, nature-centric lifestyle that they had followed for centuries. Several NGOs used videos and CDs to show the harmful effects of uranium mining at Jadugoda from the tailing ponds. This also helped in generating opposition to the mining project among the local residents.²⁴

Meghalaya: Opinion about uranium mining in West Khasi Hills appears to be divided in Meghalaya with some landowners of the project area enthusiastic about selling their land to UCIL. They feel that this would accelerate the pace of development in this remote and underdeveloped part of Meghalaya. On the other hand, student and youth organizations such as the Khasi Students Union (KSU) and some other NGOs are opposed to the project. KSU is opposing the project on three grounds: adverse effects on health from radiation, influx of outsiders, and alienation of tribal land.

Summary

Uranium mining in India appears to present a number of contradictions and complexities. While it may be premature to declare the mining and processing of uranium at Jadugoda, Jharkhand, to be either benign or harmful at the present level of our knowledge, ethically speaking, there is need for greater transparency and public participation in radioactive waste management, land acquisition and other contested areas. The ethical principles of informed consent and informed choice need to be exercised more seriously to allay the apprehensions in peoples' mind.

2.4.6. Greenhouse gas (GHG) emissions

A fourth detrimental effect of uranium mining is GHG emissions. Although nuclear reactors themselves do not emit GHGs, uranium mining is not completely GHG emission free. Mining is done using fossil fuel energy. Heavy machinery is often operated using fossil fuels, for instance. However, in comparison to fossil fuel electricity production and consumption, the levels are significantly lower.

Soon after uranium ore is mined, it is crushed and ground to a slurry in the milling process. It is then recovered as uranium oxide (U_3O_8) concentrate (WNA, 2009). Because uranium needs to be gasified before it can be enriched in gas centrifuges, the uranium oxide is converted to gaseous uranium hexafluoride (UF_6) in the conversion process (WNA, 2009). While there are small amounts of radioactivity and chemicals produced into waste, there do not appear to be significant and particular ethical concerns with the technology.

While some kinds of nuclear reactors, such as the Canadian CANDU reactors (Deffeyes, 2005), do not require enriched uranium, the vast majority of reactors in operation do. As the proportion of ^{235}U present in uranium hexafluoride is low (about 0.7%), it must be enriched to about 3.5% where it becomes usable in conventional nuclear energy reactors (WNA, 2009). This is almost always accomplished by a cascade of gas centrifuges, which successively increase the concentration of ^{235}U in the gas until it

24 *Frontline*, Volume 22, Issue 27, 31 December 2005 - 13 January 2006.

reaches an acceptable level (WNA, 2009c). The remaining ^{238}U is called “tails” and they are often referred to as “depleted uranium”,²⁵ or DU, known for high density. DU is often used to form yacht keels (WNA, 2009c), counterweights in aircraft, and radiation shielding. It is also used in weapons manufacture as defensive armour plating and armour-piercing rounds (WHO, 2003).

2.5 Nuclear Waste

Freshly spent nuclear fuel assemblies are highly radioactive and are stored in ponds usually located at the power plant. The rods stay in the ponds for several years. The ponds act as a barrier against radiation and absorb the heat from the fuel (water has a high capacity to absorb heat). Eventually, the spent fuel becomes less radioactive. The longer it is stored, the easier it is to handle, due to the decay of radioactivity (Richter, 2008). However, there is enough radiation leftover to act as a deterrent against nuclear theft or diversion (Richter, 2008). There are two alternatives for spent fuel. The first is to reprocess, and the second is long-term storage.

During reprocessing, the uranium (U) and plutonium (Pu) are separated from the wastes. The uranium is returned to the nuclear fuel cycle at the point of conversion (WNA, 2009b). This fuel contains about 50% ^{239}Pu (WNA, 2009b). The 3% wastes are eventually turned into solid wastes (WNA, 2009b). This waste can be a source of concern, as it needs to be stored.

Reprocessing has been criticized as being expensive, posing security threats, harming the environment and not eliminating the need for geological repositories. Non-government organizations (NGO) quote the economic and environmental disaster of the West Valley reprocessing facility in the U.S., the fuel leak from the Sellafield THORP reprocessing plant in the U.K. and the cost overruns of the Rokkasho reprocessing plant in Japan as some of the examples to highlight the risks of the reprocessing option (Public Citizen, 2008).

The fuel reprocessing facilities at Sellafield²⁶ in the UK have the capacity to reprocess spent fuel from hundreds of nuclear power plants (NPPs). The thermal oxide reprocessing plant (THORP) at Sellafield opened in 1994. These reprocessing facilities create large volumes of liquid high-level radioactive wastes and highly toxic mixed wastes. There has been criticism of the plan to dispose of most of these wastes in geological formations underlying the Sellafield facility because it may create a radioactive plume as large as the ones seen during Soviet or US weapons production in the 1960s.

There are also large reprocessing facilities in France at La Hague and Marcoule, and at sites in the USA, for example.

The other major sources of radioactive contamination in the United Kingdom is the Dounreay Nuclear Facility on the North coast of Scotland. Dounreay was the world's first fast breeder reactor and the site of most weapons grade plutonium production for the U.K. Much of the high level waste is expected to be released to the sea as it breaches

25 http://en.wikipedia.org/wiki/Depleted_uranium.

26 Sellafield was formerly called Windscale (a military reactor), and was the site of a 3 day fire in 1957 that released 700 TBq ^{131}I ; 40 TBq ^{137}Cs ; 4 TBq ^{89}Sr and 0.3 TBq ^{90}Sr across the UK and into Belgium (UNSCEAR, 1982). See also <http://www.davistownmuseum.org/cbm/Rad8d.html>

the tunnel cover in about 200 years time, as the storage facility is not sufficiently strong for a long storage period. Currently however, the main source of plutonium in children's teeth in the U.K. is Sellafield (O'Donnell et al., 1997).

Making weapons from spent nuclear fuel is not considered a desirable option in this report, however, a standard 1-GWe reactor produces roughly 200 kg of plutonium per year, enough in principle for about 20 weapons (Richter, 2008). Reactor-grade plutonium can be in theory used to build a "dirty bomb" which is a sub-nuclear or non-nuclear weapon causing significant loss of life and environmental damage. If the reactor-grade plutonium were available to rogue elements, it could also be used to manufacture a fission weapon, although it may be unreliable (Richter, 2008).

If the spent fuel is not reprocessed or made into weapons, it must be stored. This raises several ethical issues related to waste management decisions, intergenerational equity, and the perceived lack of information by the public. Radioactive waste lasts a long time and therefore intergenerational equity is one of the prime ethical considerations for waste management. As an illustration, the intergenerational ethical issues posed by repositories span risks pertaining to underground aquifer layers, agriculture in the vicinity of the repository site, radiation risks in the event of accidents, risks of earthquakes, and other natural calamities. The IAEA's principles on radioactive waste management (IAEA, 1995) have two specific references to intergenerational equity. Principle 4 states that "radioactive waste shall be managed in such a way that predicted impacts on the health of future generations will not be greater than relevant levels of impact that are acceptable today". Principle 5 states, that "radioactive waste shall be managed in such a way that will not impose undue burdens on future generations". Yet, implementing these principles in radioactive waste policy decision-making, given the scientific uncertainties associated with long-term health risk assessment in principle 4, and ethical considerations of what constitutes "undue burden" in principle 5, is a challenge. On the one hand, medical research is progressing on radiation-induced diseases such as cancer, and on the other hand, the health profile of the population as a whole is changing due to changing food and lifestyle habits. To avoid imposing an ethical burden on future generations with a legacy of wastes buried underground, reversibility and retrievability technologies are frequently positioned as a solution, but the costs of such options are substantial.

The timeframes are an issue for the "public" for societies in the future that we cannot yet imagine. For instance, it takes thousands of years for the high level waste, which is produced by the reactor to reach the radioactivity levels of the original uranium ore (WNA, 2009c). Further, the media often negatively portrays the generation of radioactive waste.

All of this may result in low social acceptability of radiation waste management decisions, especially by local communities. Public protests ranging from mild demonstrations to violence on the streets have been observed (Choi et al., 2008). To improve societal acceptability, many stakeholder models are evolving, especially with reference to long-term geological disposal. Despite these efforts however, much of the public is not yet persuaded.

2.6 Nuclear Fuel Cycle and Supply

A closely related issue to the nuclear fuel cycle is the supply of nuclear fuel. The main source of nuclear fuel is ^{235}U as mentioned above (See also Table 1 in Appendix). While ^{239}Pu is used in some reactors, it is derived ultimately from ^{235}U and is not considered an originating fuel. It cannot be extracted as part of an ore, and its supply depends on ^{235}U . Another possible nuclear fuel for commercial use in the future is thorium, which may be used in commercial breeder reactors.

Because about 65,000 tonnes of uranium per year are used, the amount of uranium available may be expected to last for approximately 80 years at current rates. However, such a forecast leaves out many considerations. It does not reflect the significant percentage of nuclear fuel traditionally derived from the highly enriched nuclear fuel of decommissioned nuclear weapons (from the year 2000 the dilution of 30 tonnes of military high-enriched uranium annually has been displacing about 10,600 tonnes of uranium oxide per year from mines, which represents about 13% of the world's reactor requirements) (WNA, 2009d). It does not also factor in unknown uranium deposits (which is expected to increase significantly (WNA, 2009e), which typically increase when energy prices increase because exploration is intensified; increasing efficiency of nuclear reactors; and new technology (WNA, 2009g). Finally, greater and more efficient reprocessing is likely to extend the amount of usable nuclear fuel (WNA, 2009e). Nuclear experts have expressed confidence in the supply (Deffeyes, 2006).

Most of the world's uranium is obtained from Canada (20.5%), Kazakhstan (19.4%) and Australia (19.2%) (WNA, 2009e) (See Figure 5). The current supply of uranium is therefore stable, as these countries tend to have lower political and economic risk. For instance, the UN Conference on Trade and Development Index (TDI) in 2007 ranked Canada as 10th and Australia as 16th (data on Kazakhstan was not available) (WNA, 2009e).

However, there can be significant political differences in the manner in which such resources are controlled for trade as discussed in section 1.4. For instance, some states, such as Malaysia, Indonesia, and Brazil are suspicious of their potential suppliers (Richter, 2008). The GNEP and Nuclear Supplier's group, present complex ethical issues because is it fair that the GNEP supplier nations are the only states who can supply? Which person's standards and worldview sets the policies of the Nuclear Supplier's Group?

There have been many proposals to guarantee fuel supplies to countries without uranium enrichment facilities or those who must purchase their uranium fuel. One such proposal is the Global Nuclear Energy Partnership (GNEP). Another well-known proposal, which has recently gained momentum, is the private Nuclear Threat Initiative (NTI). Mohammed ElBaradei, the former director-general of the International Atomic Energy Agency (IAEA), has laid out three principles for a fuel guarantee framework (Pomper, 2009). First, the fuel bank mechanism should be non-political, non-discriminatory, and open to any state in compliance with its IAEA safeguards obligations (Pomper, 2009). This ensures that nuclear material and technology are not diverted from peaceful to military uses (Pomper, 2009). Second, any release of the

material should be determined by non-political criteria established in advance and applied objectively and consistently (Pomper, 2009). Third, “no state should be required to give up its rights under the nuclear Nonproliferation Treaty (NPT) regarding any part of the nuclear fuel cycle.” (Pomper, 2009). Finally, “one part of a possible new framework is to reach agreement that all new enrichment and reprocessing activities should be placed exclusively under multilateral control, to be followed by agreement to convert all existing facilities from national to multilateral control as well” (Pomper, 2009).

Another way to control nuclear fuel export and transfer is through less formal political groups, such as the Nuclear Suppliers Group (NSG),²⁷ which according to its website is a “group of nuclear supplier countries which seeks to contribute to the non-proliferation of nuclear weapons through the implementation of Guidelines for nuclear exports and nuclear related exports” (NSG, 2009). Nuclear fuel, along with nuclear technology, is the group’s focus.

Enrichment is one of the most ethically controversial areas of the nuclear fuel cycle. Two ethical issues relate to its possible use in producing weapons-grade uranium and the use of depleted uranium.

Gas centrifuges are a bottleneck technology to producing weapons-grade uranium, as the technology is highly complex (Burton, 2008). However, once mastered for the purposes of producing reactor-grade uranium, it can be easily modified to produce weapons-grade uranium. If the gas centrifuges used by Pakistan for its uranium weapons were to be used to make enough fuel to power Iran’s Bushehr 1-GWe reactor, an estimated 100,000 centrifuges would be required. However, it only takes about 1,500 more such centrifuges to produce 90%-enriched uranium (i.e., weapons-grade uranium) in one year (Burton, 2008). A centrifuge three times more efficient would require 35,000 centrifuges to produce reactor-grade uranium, and only 250 additional centrifuges to produce one weapon (Burton, 2008).

The ethics of so-called “dual-use” technologies has been debated. On the one hand, restraining civilian use of nuclear energy is difficult for a number of reasons. It is guaranteed under the so-called third pillar of the Nuclear Non-Proliferation Treaty (NPT), Article IV, which provides the “inalienable right of all Parties to the Treaty to develop research, production and use of nuclear energy for peaceful purposes without discrimination”, a quasi-deontological ethic. It even provides for “due consideration for the needs of the developing areas of the world”, which includes states such as Iran which are currently under much scrutiny. Restraining access to an abundant source of energy from persons in the developing world is ethically challenging. Moreover, such nuclear energy may displace use of fossil fuel consumption, which may be beneficial to the environment considering nuclear energy’s non-existent GHG emission. Finally, energy security in the form of enrichment is not considered to be morally objectionable *per se*, especially when other nations possess such capabilities.

27 Nuclear Suppliers Group, <http://www.nuclearsuppliersgroup.org/Leng/default.htm>.

On the other hand, such technology can bring nuclear energy-using countries, which enrich their own uranium into nearly *de facto* nuclear weapon-possessing states. This may catalyze a regional arms race in volatile regions of the world, which may more than offset any international benefit that would be initially seen from reduced GHG emissions.

The possibility of proliferation-prone enrichment has led to a discussion on how to render it more proliferation-resistant. Here, the focus has been on preventing new nations from enriching and creating attractive alternatives (Burton, 2008). For instance, the Republic of Korea obtains 39% of its electricity from nuclear power and elects not to enrich nuclear fuel itself because it is a financially sound decision. However, other states such as Malaysia, Indonesia, and Brazil have voiced suspicions of potential suppliers (Burton, 2008).

DU weapons are widely criticized as being unethical. DU is weakly radioactive and due to a long half-life, remains radioactive. The aerosol produced by DU weapons can potentially contaminate wide areas as they become scattered and can be inhaled (Mitsuakou, 2003). At least one scientific study has shown that DU has carcinogenic potential (Miller, 2007). International NGOs, such as the International Campaign to Ban DU, have taken up the cause to ban such weapons. A response to the Depleted Uranium (DU) Resolution adopted at the United Nations General Assembly was developed at the Joint UNESCO-UNITAR EETAP Conference held in 2008 in Hiroshima, Japan.²⁸

Once the uranium is enriched, it is transferred to a fuel fabrication plant, where it is eventually formed as part of nuclear fuel rods and fuel rod assemblies (WNA, 2009). While there are small amounts of radioactivity and chemicals produced into waste, there do not appear to be significant and particular ethical concerns with the technology.

Once the nuclear fuel assemblies have been produced, the front end of the nuclear fuel cycle comes to an end, and the nuclear fuel assemblies enter the reactor. The ²³⁵U fissions and produces heat which is converted to electricity. It is eventually turned into plutonium and wastes (WNA, 2009a). Depending on the reactor design, fuel, and operation, about one-third of the spent fuel is removed every year or 18 months, to be replaced with fresh fuel (WNA, 2009a).

28 In response to the Depleted Uranium (DU) Resolution adopted at the United Nations General Assembly on 5 December, 2007, the participants of the Joint UNESCO-UNITAR Asia-Arab Interregional Philosophical Dialogues on the Roles of Philosophy in War and Peace, and the Joint UNESCO-UNITAR Workshop on the Ethics of Nuclear Energy Technologies, noted that they are deeply concerned about the DU issue especially because it is understood that children are most susceptible to toxic radioactive materials.

Thus, the participants considered it is urgent to:

- To alert the peoples and children living particularly in the DU-affected areas to the dangers caused by DU weapons;
- To give serious consideration to the harmful effects of DU weapons by setting up an expert committee on the DU issue as quickly as possible;
- To place an international moratorium on the use of DU weapons to prevent further DU-caused harms on human health and contamination of the environment.
- To establish a Body to transport DU polluted war machinery and ammunition away from populated areas, and to properly dispose of them in remote and safe locations.

Agreed in Hiroshima, Japan, 27 July, 2008

3. Fukushima, Chernobyl and Standards

This chapter will examine the ethics of nuclear energy technology after two events that have challenged the safety of the technology. An explosion and fire at Chernobyl nuclear power plant (NPP) in Ukraine on 26 April 1986 released large quantities of radioactive contamination into the atmosphere, which spread over much of Western USSR and Europe (Chernobyl Forum, 2006).

Fukushima Daichi NPP in Fukushima prefecture, Japan, was badly damaged in the earthquake and tsunami on 11 March 2011, and explosions in several reactors in the complex occurred as the cooling systems failed by electricity blackout, despite protection measures taken against these expected natural hazards (Japan, 2011).

Although nuclear power plant design has advanced significantly since the major construction of NPPs in the 1980s, many of the first and second generation NPPs continue to operate (Figure 8). We will explore the ethical issues through a comparison of these nuclear disasters, which have been the most significant global events influencing national policies to question the positive aspects of nuclear energy production.

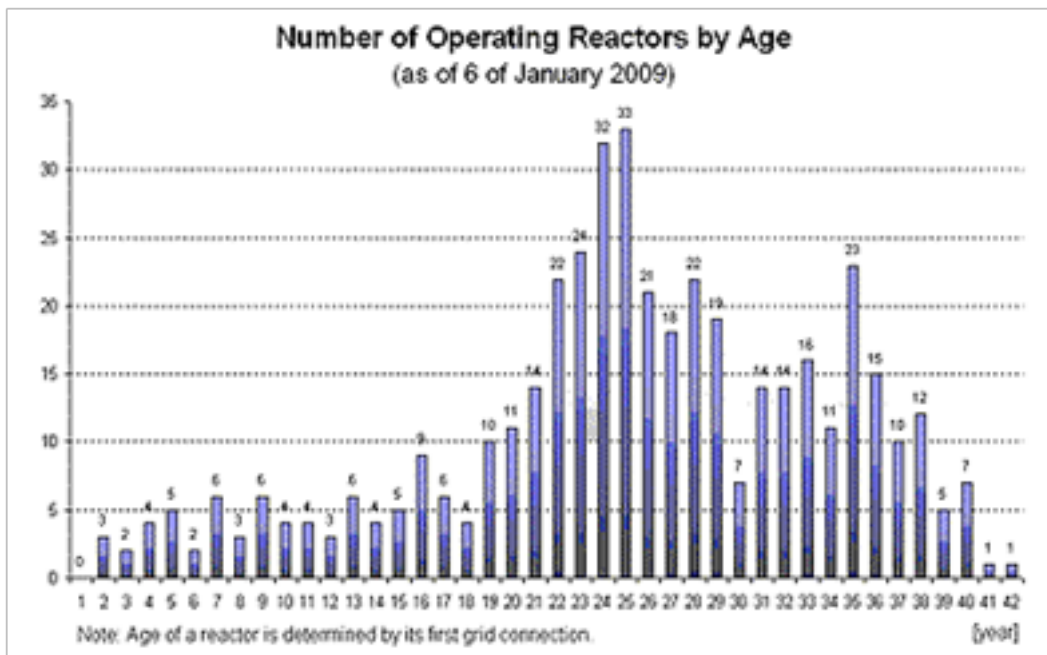


Figure 8. Number of Nuclear Reactors Worldwide by Age as of January 2009 (IAEA, 2009)

3.1. Causes of the Accidents

In the case of both level 7 incidents on the international nuclear and radiological event scale (Table 3), Chernobyl and Fukushima, a common response of authorities to the disasters was that these were early reactor designs and are unlikely to occur again. However, there are multiple factors that relate to these accidents occurring.

The Chernobyl disaster began during a systems test on Saturday, 26 April 1986 at reactor number four of the Chernobyl plant, which is near the city of Prypiat and within a close proximity to the administrative border with Belarus and Dnieper river. There was a sudden power output surge, and when an emergency shutdown was attempted, a more extreme spike in power output occurred, which led to a reactor vessel rupture and a series of explosions. These events exposed the graphite moderator of the reactor to air, causing it to ignite.²⁹ The resulting fire sent a plume of highly radioactive smoke fallout into the atmosphere and over an extensive geographical area.

The Fukushima Daichi NPP was damaged by an earthquake.³⁰ The resultant tsunami also cut off the emergency cooling systems, leading to suspected meltdowns in three reactors of the complex. In the case of Fukushima there had been documented problems over many years, and the oldest reactors in the complex of Fukushima Daichi Nuclear Power Plant (NPP) had reached expiry date. However, they had been granted licenses to continue to operate, based on financial reasons that once the plant is operating there are few costs. The economic aspects of nuclear power will be analyzed in chapter 4, however, we can note here that the company operating Fukushima, Tokyo Electric Power Company (TEPCO) had not insured the NPP because of the high costs of the insurance premium.

The IAEA (2011) expert report indicated the following accident causes by the earthquake in preliminary summary. *“Although all off-site power was lost when the earthquake occurred, the automatic systems at TEPCO’s Fukushima Dai-ichi successfully inserted all the control rods into its three operational reactors upon detection of the earthquake, and all available emergency diesel generator power systems were in operation, as designed. The first of a series of large tsunami waves reached TEPCO’s Fukushima Dai-ichi site about 46 minutes after the earthquake. These tsunami waves overwhelmed the defenses of TEPCO’s Fukushima Dai-ichi facility, which were only designed to withstand tsunami waves of a maximum of 5.7 meters high. The larger waves that impacted this facility on that day were estimated to be larger than 14 meters high. The tsunami waves reached areas deep within the units causing the loss of all power sources except for one emergency diesel generator (6B), with no other significant power source available on or off the site, and little hope of outside assistance.”*

The Japanese government in its report (Japan, 2011) focused on the tsunami as the main accident cause, “Conclusion 2: Given the extreme circumstances of this accident the local management of the accident has been conducted in the best way possible and following Fundamental Principle 3. Conclusion 3: There were insufficient defence-in-depth provisions for tsunami hazards.” (IAEA, 2011, pp.13).

Actually there was a 2008 TEPCO study indicating a 15.7 metre high tsunami would arrive at units 1-4 with and a 13.7 metre high tsunami at unit 5 and 6 if the same magnitude 8.3 Meiji Sanriku earthquake of 1898 occurred. This means that this tsunami

29 International Atomic Energy Agency - Division of Public Information. 2005. *Frequently Asked Chernobyl Questions*. Retrieved 23 March 2011.

30 TEPCO. 2011. Summary of the Report on the Analysis of Observed Seismic Data Collected at Fukushima Daiichi Nuclear Power Station and Fukushima Daini Nuclear Power Station pertaining to the Tohoku-Taiheiyu-Oki Earthquake. http://www.tepco.co.jp/en/press/corp-com/release/betu11_e/images/110516e27.pdf

is not an unforeseeable disaster that the company had publicly been saying after the accident.³¹

Actually in a 1993 earthquake southwest of Hokkaido with magnitude 7.8 the Cabinet Office of the Government of Japan (2005) reported that the maximum water height was 31.7m in the Monai district of Okushiri island in Hokkaido. In the area there are many ancient stone warnings of Tsunami as well (Kingston, 2011). Therefore many critics accuse the company of not preparing sufficiently high defenses around the NPP, and one will expect such defenses may be prepared around other NPPs to protect them from future tsunamis.

The direct failure of the cooling systems was electrical blackout. The U.S. NRC had already published that a station blackout was a severe accident risk at Peach Bottom NPP that had same type of reactor (Boiling water reactor made by General Electric (GE) as Fukushima Daiichi reactors in 1990. Gould (1992) showed that Peach Bottom nuclear power plant had some radiation leaks by mechanical accidents caused by operator error. In short, blackout by not only the tsunami as well as earthquake but also human error led to the nuclear accident.

There is evidence that the primary electrical supply was cut by the earthquake because the reactor pressure vessel had some design flaws. Problems with the fractured, deteriorating, poorly repaired pipes and the cooling system had been pointed out for years, and in September 2002, Tepco admitted covering up data about cracks in critical circulation pipes.³² The same investigation by *Independent Asia* reports that workers reported leaking pipes after the earthquake, as well as damage to the walls of the reactor. Some of the affected pipes were to deliver coolant to the reactor. A radiation alarm one mile from the NPP went off before the tsunami hit, indicating damage to the reactor.

On 2 March 2011, nine days before the meltdown, the Nuclear Industrial Safety Agency (NISA) warned Tepco on its failure to inspect critical pieces of equipment at the plant, including recirculation pumps. Tepco was ordered to make the inspections, perform repairs if needed and report to NISA on 2 June.³³

The Nuclear Emergency Response Headquarters of the Government of Japan (Japan, 2011, pp.29-30) wrote to IAEA that, *"A major cause for this accident was a failure in securing the necessary power supply. This was caused by the facts that power supply sources were not diversified from the viewpoint of overcoming vulnerability related to failures derived from a common cause by an external event, and that the installed equipment such as a switchboard did not meet the specifications that could withstand a severe environment such as flooding. Moreover, it was caused by the facts that 30 battery life was short compared with the time required for restoration of AC power supply and that a time goal required for the recovery of external power supply was not clear."*

There was still direct human error in the manual operation of the Isolation Condensor (IC). The operator can use the IC without electric power. TEPCO had created a manual for operation and management in the case the reactor stopped. In the manual by TEPCO, when water for cooling the reactor decreases temperature over 55 degrees in 1 hour,

31 Yomiuri Newspaper, 28 August 2011.

32 Independent Asia, 2011.

33 Citizen's Nuclear Information Centre, 2011.

the operator should manually stop the emergency isolation condenser to protect the reactor (for future use of the reactor). In the official report it reads, *“Operators of TEPCO followed TEPCO’s manuals for severe accidents and urgently attempted to secure power supplies in cooperation with the government, in order to recover many equipment of the safety systems while the core cooling equipment and the water-injection equipment which 8 automatically started up were operating. However, they could not secure power supplies after all. Since the core cooling functions using AC power were lost in Units 1 to 3, the core cooling functions without using AC power operated or attempted were made to that end. These are the operation of the Isolation condenser in Unit 1, the operation of reactor core isolation cooling system (RCIC) in Unit 2 and the operation of RCIC and high pressure injection system (HPCI) in Unit 3. These core cooling systems that do not utilize AC power supplies stopped functioning thereafter, and were switched to alternative injection of fresh water or sea water by the fire distinguishing line using fire engine pumps. Concerning Units 1 to 3 of Fukushima Dai-ichi NPP, as the situation where water injection to each RPV was impossible continued for a certain period of time, nuclear fuels in each reactor core were not covered by water but were exposed, and led to a core melt. A part of the melted fuel stayed at the bottom of the RPV.”* (Japan, 2011, pp. 7-8). There has been considerable debate on this issue, because if the IC had not been shutdown at intermittent periods by human operators, the temperature of the core would have fallen more rapidly and it is possible the core had not been exposed to the air, and also that the temperature of the exposed material would have been cooler, which may have avoided the meltdown. Under investigation by the Special Committee for Promotion of Science and Technology Innovation’s Extraordinary Committee for Exploration of Accident Cause at the House of Representatives on 8 September 2011, TEPCO submitted the operation manual concerning severe accidents with blacked out words.

The actual story may not be available for some time in the future. TEPCO has accused the person for stopping the isolation condensor, however, it appears they may have been following the instruction manual. This would indicate a systemic error that the economic value of the reactor was placed above human and environmental safety and prevention of a meltdown. The damage caused by the earthquake suggests that other NPPs in Japan may suffer from earthquake damage, even without a tsunami.

There are 51 reactors with 49 GW maximum capacity in 13 prefectures in Japan as of 1 July 2011. The number of reactors is third highest in the world. The Japanese government and electric companies constructed many NPP with the support of the US government after the enactment of the Atomic Energy Basic Law on 19 December 1955. Japan needs to import some 80% of its energy requirements. The country’s 50 main reactors provide some 30% of the country’s electricity and this had been expected to increase to at least 40% by 2017 (WNA, 2011). However, as of September 2011 only 11 NPPs were generating electricity.

Nuclear science will continue to develop in attempting to deal with both Chernobyl and Fukushima, with some experience of how to deal with critical situations in both cases. There will also be investigations of how to decontaminate land, water, and to decommission NPP that have experienced meltdowns. We can note that previous data and analyses to predict the disasters and preventive measures did exist, and these experiences reveal that management systems are not always applied although nuclear

science itself may have prepared recommendations.

3.2. Environmental Spread of Radioactivity

As discussed before there are seven levels of nuclear accident, and there have been two accidents considered at level seven, the highest level (Table 3). The reason that these two accidents are rated at level 7 is because of the release of radioactive isotopes over a large area in significant amounts. The Chernobyl case involved a meltdown and Fukushima case two meltdowns, of which one may be called a melt-through. Radioactive materials are carried by wind currents and hotspots of fallout occur after rain including radioactive materials deposits more of the material. In Fukushima case there is also ocean dispersal of radioisotopes, which has been compared to the scheduled discharges from nuclear reprocessing facilities such as Sellafield in the U.K., which for example in the late 1970s was releasing over 8,000 TBq annually as a mixture of isotopes into the ocean (UNSCEAR, 1982). We can also consider the significant releases of radioactivity into the environment from atomic bomb testing.

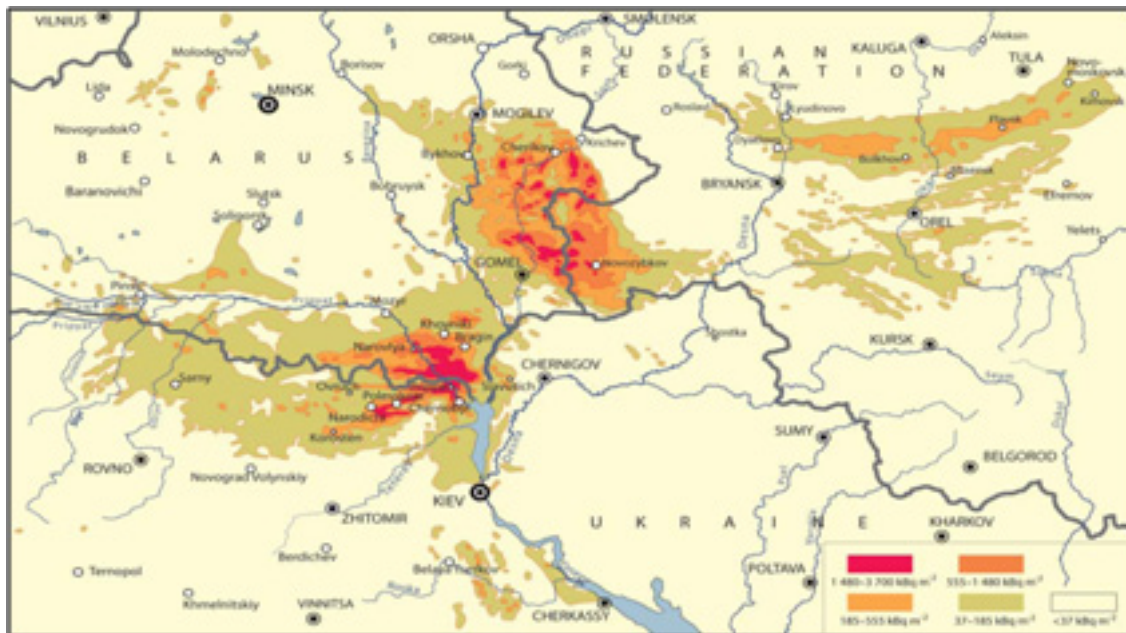


Figure 9: Map of ^{137}Cs deposition levels in Belarus, the Russian Federation and Ukraine as of December 1989. Source: International Advisory Committee. 1991. The International Chernobyl Project. Technical Report. IAEA, Vienna.

3.2.1. Chernobyl

The plume from the two explosions at Chernobyl drifted over large parts of the western Soviet Union and Europe. From 1986 to 2000, 350,400 people were evacuated and resettled from the most severely contaminated areas of Belarus, Russia, and Ukraine.³⁴

34 UNDP and UNICEF. 2002. The Human Consequences of the Chernobyl Nuclear Accident.. 22 January 2002. p. 32 (Table 2.2 Number of people affected by the Chernobyl accident (to December 2000)). Retrieved 17 September 2010.

According to official post-Soviet data, about 60% of the fallout landed in Belarus.³⁵ The spread of radioisotope ^{137}Cs is shown in Figures 9 and 10. Contamination from the Chernobyl accident was scattered irregularly depending on weather conditions, but rain was purposely seeded over the Byelorussian Soviet Socialist Republic by the Soviet air force to remove radioactive particles from clouds heading toward highly populated areas. This applied the ethical principle to minimise harm, although it may have led to higher exposure for some persons under the rain!

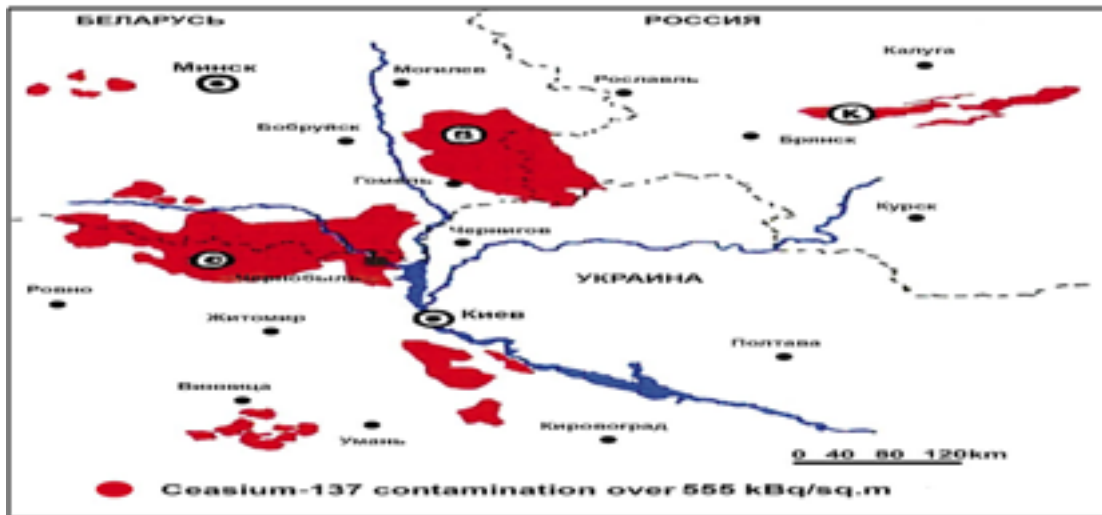


Figure 10: ^{137}Cs content around Chernobyl (Red areas are more than 555kBq/m²) Source: UNDP. 2006. National Belarussian Report. 2006. 20 years after the Chernobyl Catastrophe. The Consequences in the Republic of Belarus and their overcoming. pp.8.

3.2.2 Fukushima

The spread of radioactive cesium from the Fukushima reactor explosions is shown in Figure 11. Although there are records of measurements about radioactive isotopes at various locations in Japan, and in various vegetables and fish from different places (Obata, 2011), there have been controversies regarding where these samples were taken from (Uejima, 2011).

The French nuclear agency, IRSN, published many analysis concerning Fukushima Daiichi accident.³⁶ When they compare the figures from joint U.S.-Japanese aerial surveys with estimation of doses the first year by external radiation, we can understand that condition of total cesium deposition overlaps with condition of estimation of dose received over the first year by external radiation.

Chernobyl releases came from two explosions and a fire. The Fukushima NPP involved several explosions, as shown in Figure 12. The estimates by Japanese authorities one

35 Environmental consequences of the Chernobyl accident and their remediation: Twenty years of experience. Report of the Chernobyl Forum Expert Group 'Environment'. Vienna: International Atomic Energy Agency. 2006. p. 180. ISBN 92-0-114705-8. Retrieved 13 March 2011.

36 IRSN is a public authority with industrial and commercial activities, placed under the joint authority of the Ministry for Ecology, Energy, Sustainable Development and Town and Country Planning, the Ministry for the Economy, Industry and Employment, the Ministry for Higher Education and Research, the Ministry of Defense and the Ministry for Health and Sports. See <http://www.irsn.fr/EN/Pages/home.aspx>

month after the accident suggested that the total amount of radioactive materials released by then was equal to only about 10 percent of that released in the Chernobyl accident.³⁷ However, at a separate news conference, an official from the plant's operator, TEPCO, said, "The radiation leak has not stopped completely and our concern is that it could eventually exceed Chernobyl." In addition, as discussed below, figures on neptunium (Ne) and plutonium (Pu) releases from Unit 3 reveal total levels higher than Chernobyl.³⁸

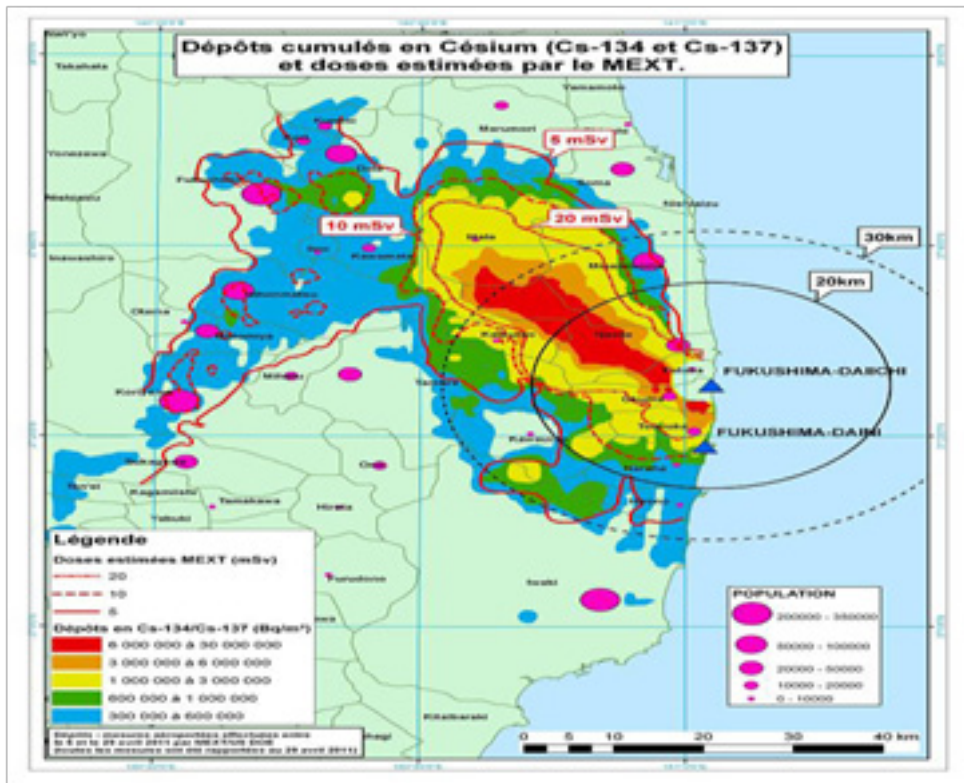


Figure 11: Radioactive cesium spread from Fukushima and estimated radioactive dose. Overlay of deposits of ^{137}Cs + ^{134}Cs and doses calculated for the first year for 3 dose levels (5, 10 and 20 mSv). Source: IRSN. 2011. Évaluation au 66ème jour des doses externes projetées de l'accident nucléaire de Fukushima, pp.16.

Dr Tatsuhiko Kodama, a professor at the Research Centre for Advanced Science and Technology and Director of the University of Tokyo's Radioisotope Centre Kodama's centre, using 27 facilities to measure radiation across the country, has been closely monitoring the situation at Fukushima. He said in a 27 July 2011 speech to the Committee of Health, Labour and Welfare at Japan's House of Representatives, "the total amount of radiation released over a period of more than five months from the ongoing Fukushima nuclear disaster is the equivalent to more than 29 Hiroshima-type atomic bombs and the amount of uranium released is equivalent to 20 Hiroshima bombs.

37 According to Hidehiko Nishiyama, Deputy Director General of Japan's nuclear regulator, the Nuclear and Industrial Safety Agency, in *NY Times* (11 April 2011). See also <http://www.nytimes.com/2011/04/12/world/asia/12japan.html>

38 See <http://www.meti.go.jp/press/2011/06/20110606008/20110606008.html>

NISA published its estimate of radiation leak in the air from Fukushima NPP for the period 11 March to 5 April 2011 only, with comparisons to the 1945 Hiroshima atomic bomb on 26 August 1945 for several nuclear species. For ^{89}Sr Fukushima released 2.0×10^{15} Bq (18 fold Hiroshima), ^{90}Sr 1.4×10^{14} Bq (2.4 fold), for ^{131}I , 1.6×10^{17} Bq (2.5. fold) and for ^{137}Cs 1.5×10^{16} Bq (169 fold Hiroshima).³⁹

However, when we consider the list of radioisotopes released to the press by the METI briefing in June 2011⁴⁰ there were high levels of plutonium released, which increased the amount of radioactive substances admitted to be released by 23 thousand times that estimate. The reason was that Unit 3 in Fukushima Daiichi used MOX fuel that contains plutonium and it is shown that a lot of neptunium (^{239}Np) was released by the damage and explosion. ^{239}Np transforms to ^{239}Pu by β -collapse with a half-life of 2.4 days.⁴¹ In other words, half the ^{239}Np becomes ^{239}Pu in 2.4 days. In the case of Chernobyl disaster, the Geochemical Research Department, Meteorological Research Institute, Japan (2007) published that Chernobyl released 60TBq of ^{234}Pu and ^{240}Pu .⁴²

Fukushima data shows 76TBq of ^{239}Np were released, making it equivalent to 72 thousand Hiroshima bombs, not 20! Perhaps there is still more data to be released, but the ethical points remain the same. Plutonium releases α -rays that strongly damaging to health for internal exposure for long periods. Dr.Kazuko Shichijo in Nagasaki University published in 2006 the discovery that plutonium remaining in death ash by the atomic bombs kept on emitting α -rays in dead cells from bone and kidney 60 years after death due to radiation exposures from the atomic bombs.⁴³

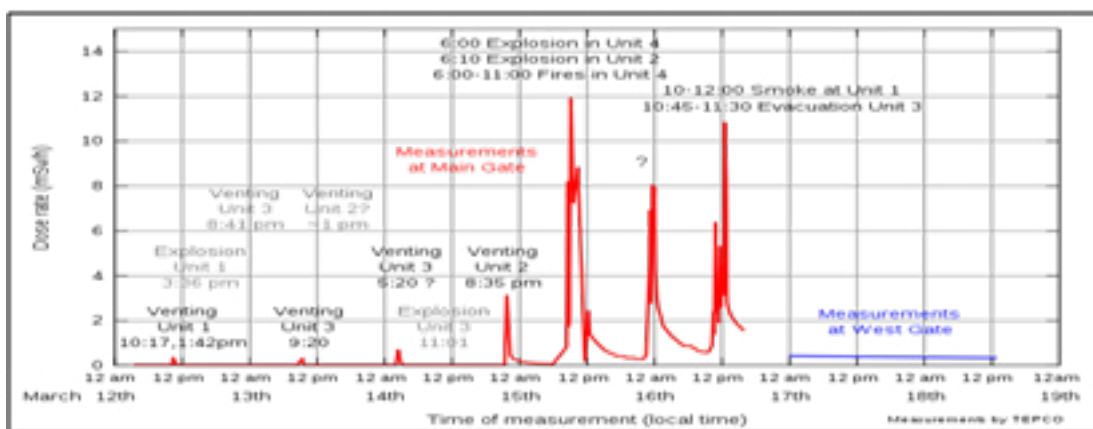


Figure 12: Radiation release into the air during venting hydrogen explosions and fires at Fukushima. Measurement data from TEPCO, measured dose rates at main gate (except measuring point from 10 am on 12 March to 12 pm on 18 March 2011 was the west gate of Fukushima Daiichi NPP).

Source: Wikipedia (2011), "File:FukushimaDosis gtl1 en.sggv"

http://en.wikipedia.org/wiki/File:Fukushima_Dosis_qtl1_en.svg

39 Source: NISA. 2011. See <http://www.meti.go.jp/press/2011/08/20110826010/20110826010-1.pdf> <http://www.meti.go.jp/press/2011/08/20110826010/20110826010-2.pdf>

40 See <http://www.meti.go.jp/press/2011/08/20110826010/20110826010-2.pdf>

41 <http://en.wikipedia.org/wiki/Neptunium>

42 Geochemical Research Department, Meteorological Research Institute, JAPAN, "Artificial Radionuclides in the Environment 2007", http://www.mri-jma.go.jp/Dep/ge/2007Artifi_Radio_report/Chapter5.htm

43 NHK. June 2009. See http://www.youtube.com/watch?feature=player_embedded&v=pUU0I74UNp0#at=140

3.2.3. Comparisons of Releases at Fukushima and Chernobyl

Nuclear isotopes each have different fusion points, and half lives. Hotter temperature of nuclear fuel causes more leak of radioactive materials in the air. In the other words, the mechanical structure of power plant, quantity and quality of nuclear fuels, weather conditions including wind and rain as well as geographic conditions including land features and location from the source affect the condition of pollution.

Table 4: Comparisons between Fukushima and Chernobyl (as of July 2011)

Level of pollution	Fukushima Daiichi disaster	Chernobyl disaster
Quantity of radiation leak	630,000TBq of Iodine in the air*1 72TBq in the sea*2 60TBq of 234Pu	5,200,000 TBq of Iodine in the air *1 60TBq of 234Pu
Zone and population of first evacuation	20km zone (78,554 persons) *3	30km (135,000 persons) *4
Population and surface concerning first evacuation	78,200 persons (evacuation area in 20 km radius from Fukushima Dai-ichi NPP and 10 km radius from Fukushima Dai-ni NPP); 62,400 persons ("stay in-house" area between 20 km and 30 km radius from Fukushima Dai-ichi NPP) *4 628km ² within 20km zone *5	135,000 persons 2,830km ² within 30km zone *5
Condition of the highest polluted area	3 -15 MBq/m ² (accumulation of ¹³⁷ Cs), 100-500mSv*5 (estimation of external exposure for a year after disaster)	7,4 MBq/m ² (accumulation of ¹³⁷ Cs) >100mSv*45 (estimation of external exposure for a year after disaster)
Nuclear Fuel	295 tons *6	180 tons*7

Sources *1 Kawata, T. 2011. Problem of land pollution and action, 16th conference of nuclear safety commission, pp.13, See <http://www.aec.go.jp/jicst/NC/iinkai/teirei/siryoy2011/siryoy16/siryoy2.pdf>

*2 Akahata Newspaper. 2011. Leak of 72 teraBq to the sea. 30 May 2011. See <http://www.jcpre.com/genpa-fukushima2011-3/2011-5-30gen.html>

*3 TaniKenji. 2011. Map and GIS Data of Contour, Altitude and Population related to the Great East Japan. See http://ktgis.net/tohoku_data/tsunami_area_population.html

*4 Japan. 2011. pp. V-8.

*5 IRSN. 2011. Évaluation au 66ème jour des doses externes projetées de l'accident nucléaire de Fukushima, pp. 28, See http://www.irsn.fr/FR/Actualites_presse/Actualites/Documents/IRSN_Rapport_Evaluation_Dosimetrique_Fukushima_16052011.pdf

*6 STEPSCO. 2011. Summary of Fukushima Daiichi NPP, See <http://www.tepco.co.jp/nu/f1-np/intro/outline/outline-j.html>

*7 Radiation Effects Research Foundation. 2011. Q and A about leak of radioactive material by Chernobyl disaster. See <http://www.rerf.or.jp/general/qa/qa12det.html>

However, in the case of Fukushima, when a lot of radioactive materials leaked by dry vent and high temperature by phreastic explosion, most radioactive materials fell in the Pacific ocean by the predominant airflow in the winter season. Though containment and pressure vessels have some cracks and meltdown of nuclear fuel, polluted areas are smaller than the Chernobyl accident. Although Fukushima Daiichi NPP has more nuclear fuel in the 4 affected reactors of the 6 at Fukushima than the nuclear fuel in the 1 reactor of Chernobyl, there appears to be a broader area around Chernobyl affected by ^{131}I and ^{137}Cs than near Fukushima-Daiichi.

The scale of the explosion was reduced in Fukushima by the pumping of sea water into the over-heating reactors as an emergency measure to keep the temperature lower to lessen the melting of the core. The ethical judgment was made that some inevitable ocean spread of radioactivity was less harmful than a larger explosion spreading more radioactive substances over a larger area of Japanese land.

Comparison of Fukushima Daiichi accident and Chernobyl accident are in Table 4. Chernobyl leaked radiation in the air, 26 April 1986, but the Soviet government could stop most leaks of radiation in 11 days on 6 May 1986 (WNA, 2011). In the case of Fukushima, recovery of the cooling system and restoration of all facilities for reducing high risk is proving difficult, with breakage of various facilities even after the breakdown of the cooling system of 4 reactors of the 6 Units and each spent fuel pool. This means extension of the term of the severe environmental pollution.

The size of the zone and population of first evacuation in the 20km zone in Fukushima was 78,200 persons from an area of 628km², with a further 62,400 persons in the area between the 20km and 30km radius who were later evacuated. The total is similar to those evacuated from the 30km zone in Chernobyl 135,000 persons from 2,830km². The estimated value of emission of radioactive material to the air in Fukushima by NISA (Nuclear and Industrial Safety Agency) of Ministry of Economy, Trade and Industry (METI) for the period 11 March – 16 March 2011 was on 12 April 2011 said to be 370,000 TBq, but on 6 June that was increased to 770,000 TBq, and when the total list of isotopes is examined the number is considerably greater. The final estimate at Chernobyl was 5,200,000 teraBq (Table 4).⁴⁴Fukushima Daiichi keeps on emitting radioactive materials to the air.

3.3. Health effects of radiation

The Chernobyl accident occurred in 1986, and in the subsequent years a number of physical and psychological⁴⁵ diseases, and deaths have been recorded, among persons of all ages including those in utero. There were 237 people documented to suffer from acute radiation sickness (ARS), of whom 31 died within the first three months.⁴⁶ Most of these were fire and rescue workers trying to bring the accident under control, who

44 Nuclear Energy Agency, OECD. 2002. *CHERNOBYL Assessment of Radiological and Health Impacts 2002 Update of Chernobyl: Ten Years On*, pp.55-57.

45 Radiation Effects Research Foundation. 2011. Mental disability and growth impairment among survivors exposed *in utero*; See http://www.rerf.or.jp/radefx/uteroexp_e/physment.html

46 Hallenbeck, William H (1994). *Radiation Protection*. CRC Press. p. 15.

were not fully aware of how dangerous exposure to the radiation in the smoke was. The Chernobyl Forum (2006) expert group study of the 237 emergency workers diagnosed with ARS, found that ARS was identified as the cause of death for 28 of these people within the first few months after the disaster. There were no further deaths identified, in the general population affected by the disaster, as being caused by ARS.

Of the 72,000 Russian emergency workers being studied, 216 non-cancer deaths are attributed to the disaster, between 1991 and 1998. The latency period for solid cancers caused by excess radiation exposure is 10 or more years; thus at the time of the 2006 report being undertaken, the rates of solid cancer deaths were no greater than the general population. Some 135,000 people were evacuated from the area, including 50,000 from Pripyat.

For the post-Chernobyl period (1986-2002), 2674 cases of thyroid cancer in patients born in 1968-1986 have been reported in the contaminated areas, among them 1887 were children during the accident, and 787 were adolescents. This includes 62 cases reported in children born after 1986. The Register comprises 2736 cases of thyroid carcinomas operated in the period 1986–2002.⁴⁷ Overall the Chernobyl Forum (2006) predicts that 3940 total deaths will be attributed to the Chernobyl accident.

A nuclear emergency was declared by the Japanese Government at 19:03 on 11 March 2011. Initially a 2km, then 10km evacuation zone was ordered. Later the then Prime Minister Naoto Kan issued instructions that people within a 20km zone around the plant must leave, and urged that those living between 20km and 30km from the site to stay indoors. Those in the zone between 20km and 30km from the facility were subject to voluntary evacuation. The 20km evacuation zone was not strictly enforced, and residents were reported to have returned to their homes to recover valuables. In an apparent change in policy, on 21 April 2011, the Japanese government formally announced that the 20km evacuation zone would be more strictly enforced, and that only one person per residence could return for a maximum of two hours.⁴⁸ Then on 22 April 2011, the Japanese government announced that the evacuation zone would be extended from the 20km “circular” zone to an irregular zone extending northwest of the Fukushima site in accordance with ground levels of radioisotopes (refer to Figure 11). On 16 May 2011, the Japanese government began evacuating people from outside the official exclusion zone, including the village of Iitate, where high levels of radiation had been repeatedly measured. Approximately 146,000 persons were directly affected, and the total including voluntary movements is still unknown.

On 30 March 2011, the IAEA announced that 20 MBq/m² of ¹³¹I were found in samples taken from 18 to 26 March 2011 in Iitate, Fukushima, 40km northwest of the Fukushima I reactor. The IAEA recommended expanding the evacuation area, based on its criteria of 10 MBq/m². Secretary Edano stated the government would wait to see if the high radiation continued. On 31 March 2011, the IAEA announced a new value of 7 MBq/m², in samples taken from 19 to 29 March 2011 in Iitate. The ¹³¹I decays at 8% to 9% each

47 Jacob, P. et al. 2005. *Cancer in Ukraine and Belarus after the Chernobyl Accident: Baseline and Total Incidence* See http://www.bmu.de/files/strahlenschutz/schriftenreihe_reaktorsicherheit_strahlenschutz/application/pdf/schriftenreihe_rs668_appendix10.pdf

48 See Ministry of Economy, Trade and Industry (2011), news release 東北太平洋沖地震被害情報第45報, April 1 17:30, pp.11. <http://www.nisa.meti.go.jp/oshirase/2011/files/230401-4-1.pdf>

day. In spite of exposed people that needed decontamination in 20km zone, Fukushima government didn't use stable iodine to people.

The Nuclear Emergency Response Headquarters of the Government of Japan (Japan, 2011, pp. VII-8) noted that Fukushima prefectural government didn't ensure that the evacuated persons got non-radiative iodine to help their thyroid avoid uptake of ^{131}I , saying, *"On March 16 the Chief of the Nuclear Emergency Response Local Headquarters instructed the Governor of Fukushima Prefecture and others to have residents take stable iodine when evacuating from within the 20 km radius of the nuclear power plant taking into account the technical advice (Japan, 2011, VII -9) from the Nuclear Safety Commission recommending that stable iodine be administered to residents remaining in the area (within 20 km) upon evacuation. Although the completion of evacuation was acknowledged, this instruction was given as cautionary measure assuming there might be cases in which residents who couldn't evacuate were left behind. But as a matter of fact no residents took stable iodine based on this instruction because the evacuation had already been completed at the time the instruction was issued. Also, on March 21, the Chief instructed the Governor on precautions necessary in administering stable iodine."*

Six weeks after the crisis began, plans were announced for a large-scale study of the environmental and health effects of radioactive contamination from the nuclear plant. Academics and researchers from across Japan are conducting research with the Fukushima Prefectural Government. As of now the reported symptoms from several hundred patients show similar features to the radiation sickness data from survivors of Hiroshima and Nagasaki atomic bomb exposures. There have also been increased suicides in some areas.

Workers exposed to high levels of external and internal radiation in both Chernobyl and Fukushima have had the highest documented health problems. In Japan the Ministry of Health, Labour and Welfare raised the annual permitted dose for workers in the affected areas to 250mSv per year from 100 mSv per a year on 15 March 2011. In Fukushima a number of retired and older workers have volunteered to work for the high exposure environments, although the first two deaths of the accident were junior workers of age 21 and 24 years who were employed by sub-sub contractors of TEPCO, and were ordered to investigate the reactors as the tsunami was coming.⁴⁹

*Mainichi Daily News*⁵⁰ published that of 2894 workers in Fukushima Daiichi at 21 July 2011, 2570 workers were under subcontracts. Most of workers are part time jobs with subcontracts. Although TEPCO pays 100,000 Yen in a day for a worker to the contracted workers, a worker of sub-sub contractors may only receive 8,000 yen after money is taken by 5 or 6 sub companies.⁵¹ Halo-work is the name of public employment office introduced the following part time job that sub companies required in Fukushima NPP. "No previous work experience required, daily income: 9000-10,000 yen"⁵²

49 Mainichi Daily News, 2 August 2011, See <http://mainichi.jp/select/biz/news/20110802k0000e040078000c.html>; See 2 August 2011, <http://mainichi.jp/select/jiken/news/20110802k0000m040144000c.html>

50 Mainichi Daily News, 25 July 2011, See <http://mainichi.jp/select/weathernews/20110311/verification/news/20110725ddm010040013000c.html>

51 J-cast news, 5 August 2011, See <http://www.j-cast.com/2011/08/05103752.html>

52 Halo-work of public employment office, See http://job.j-sen.jp/hellowork/job_3373229/

The Ministry of Health, Labour and Welfare said that TEPCO didn't finish measurement about radiation exposure of workers.⁵³ HLWM published TEPCO measured radiation exposure about 2200 workers in about 4300 workers and TEPCO didn't contact about 1300 workers of sub contractors for measurement.

More time and data are required to fully document the health consequences in Fukushima. When we consider population density in Japan, we may understand that population in polluted areas exposed to high radiation may be larger than the population in highly polluted areas after the Chernobyl accident. Around 7 million persons receive social and medical allowances due to the Chernobyl accident (Chernobyl Forum, 2006).

In May 2011 many children in Fukushima that attended their school or kindergartens were exposed to a high level of radiation, around 20 mSv per year or higher. The Japanese government is using a 20 mSv/year standard for the public in designated radiation affected areas the Ministry of Education, Culture, Sports, Science and Technology (MEXT) adopted a 20 mSv per year standard to children in Provisional Guidelines for the Utilization of School Buildings, Grounds, and Related Facilities in Fukushima Prefecture on 19 April 2011.⁵⁴ Schools are being surveyed⁵⁵ and reveal significant levels of radiation, with a number of ethical issues because children are more at risk to harm from radiation, especially internal exposure because of their expected longer lives to be carrying internal radioisotopes.

3.4. Changing Limits of Permitted Radiation Exposure

The Japanese government changed the standard level of exposure to radioactivity in environment, food and beverages on 17 March 2011,⁵⁶

"On March 11, 2011, the Prime Minister had issued a declaration of a nuclear state of emergency relating for the accident at Tokyo Electric Power Company's Fukushima Daiichi Nuclear Power Plant. Therefore, from the perspective of the Food Sanitation Act, which aims to prevent sanitation hazards resulting from eating and drinking, and thereby protect citizen's good health, the "indices relating to limits on food and drink ingestion" indicated by the Nuclear Safety Commission of Japan shall be adopted for the time being as provisional regulation values, and foods which exceed these levels shall be deemed to be regulated by Article 6, Item 2 of the Food Sanitation Act. We would like you to take adequate measures in terms of sales and other areas, to ensure that such foods are not supplied to the public to eat. Inspections shall be conducted by referring to the office memo "Manual for Measuring Radioactivity of Foods in Case of Emergency" dated 9 May 2002."

53 Nippon Television, 11 July 2011 1:14pm, See <http://www.news24.jp/articles/2011/07/01/07185547.html>

54 MEXT. 19 April 2011, See http://www.mext.go.jp/b_menu/houdou/23/04/1305174.htm

55 MEXT. 2011. Results of dose rate measurement at schools in Fukushima Prefecture (Resurveyed). Surveyed on April 14, 2011; See http://www.mext.go.jp/component/english/_icsFiles/afieldfile/2011/04/25/1305394_0419_1.pdf

56 Handling of food contaminated by radioactivity" that Ministry of Health, Labour and Welfare (MHLW) reported for All Prefectural Governors All Mayors in cities with Public Health Centers All Mayors of Special Wards at 17 March 2011.

The Food Safety Commission in the Japanese Cabinet Office (FSCJ) released the following comment on 29 March 2011,

“Due to this radiation leakage, from the perspective of the Food Sanitation Act, which aims to prevent sanitation hazards resulting from eating and drinking, the “Indices relating to limits on food and drink ingestion” indicated by the Nuclear Safety Commission of Japan was adopted for the time being as provisional regulation values. So the foods which exceed these levels are regulated to ensure those foods are not supplied to the public to eat, and local governments have been notified by the Ministry of Health, Labour and Welfare on 17 March 2011. This provisional regulation values were adopted without an assessment of the effect of food on health by FSCJ because of its urgency, therefore on 20 March 2011, the Minister of Health, Labour and Welfare requested FSCJ for an assessment of the effect of food on health.”⁵⁷

The standards for Japan⁵⁸ and internationally vary for the accepted radioactive contamination of food and other ingested products, are shown in Table 5. The radioactive cesium limits were established in 1986 after the Chernobyl accident.

Japan utilized the guidelines for drinking water quality that WHO published in 2004 for the limits of radiation in water until the 17 March 2011, then changed them. The Ministry of Health, Labour and Welfare (MHLW) released radiation values of some limited nuclear species like ¹³⁴Cs, ¹³⁷Cs, ¹³¹I, ¹³²I in each area of Japan after the Fukushima disaster to the general public. They have not released limits on α-ray like uranium in water yet. The Japanese government made the interim standard that was based on the global guidelines of International Commission on Radiological Protection (ICRP).⁵⁹

Although the normal environmental standard for radiation in air by the Japanese government was 1 mSV per year for all general public except those who work with radioactivity in reactors of NPP, ICRP suggested to the Japanese government to change that level from 1 - 20 mSV for the year of the restoration period to avoid evacuation of inhabitants in polluted areas because of the leaks of radioactivity over a long period at 21 March 2011.

ICRP has 3 periods for environmental standard concerning radioactivity. The normal period is under 1 mSV per year. The emergency period is 20~100 mSV per year. The restoration period is 1~20 mSV per year. The change has important meanings for the link between the evacuation orders by the government and future expected payment of compensation by TEPCO.

For example, inhabitants take over environmental standard of normal period beyond 1 month for 0.0028 mSV in Minami Soma city in Fukushima. Therefore, in the case of 1m SV of normal environmental standard, even if condition of reactor changes to restoration period from emergent period, inhabitants should emigrate away. However, in the case of 1~20 m SV standards as a so-called “restoration period”, inhabitants need

57 Food Safety Commission, Japanese Cabinet Office. 2011. Radioactive contamination of food in Japanese Cabinet Office, http://www.fsc.go.jp/english/emerg/radiological_index.html

58 MHLW. 2011. No. 0317 Article 3 of the Department of Food Safety, 17 March 2011, URL:<http://www.mhlw.go.jp/stf/houdou/2r9852000001558e-img/2r98520000015av4.pdf>

59 Asahi newspaper. 26 March 2011, <http://www.asahi.com/national/update/0326/TKY201103260337.html>

not emigrate and evacuate from Minami Soma city. Though inhabitants can come back home and stay in their home, the change of environmental standard for restoration period raises ethical issues of health exposures and government responsibility. Some compensation would be expected for the increased health risks from TEPCO, as well as for the breakdown in community structures and other socio-economic impacts.

Table 5: Indices relating to limits on food and drink ingestion

Nuclide	Index values relating to ingestion limits in guidelines for coping with disasters at nuclear facilities etc. (Bq/kg)	Limits since 17 March (Bq/kg)	Limits before 17 March (followed WHO guidelines)
Radioactive iodine (Representative radio-nuclides among mixed radio-nuclides: ¹³¹ I)	Drinking water	300	10 Bq/L of ¹³¹ I
	Milk, dairy products*		-
	Vegetables (Except root vegetables and tubers)	2,000	-
Radioactive cesium	Drinking water	200	10 Bq/L of ¹³⁴ Cs, ¹³² Cs
	Milk, dairy products		-
	Vegetables	500	370 Bq/kg in total
	Grains		
Uranium	Infant foods	20	-
	Drinking water		15 µg/L of uranium value that is based on its chemical toxicity for the kidney
	Milk, dairy products		-
	Vegetables	100	-
	Grains		-
	Meat, eggs, fish, etc.		-
Alpha-emitting nuclides of plutonium and transuranic elements (Total radioactive concentration of ²³⁸ Pu, ²³⁹ Pu, ²⁴⁰ Pu, ²⁴² Pu, ²⁴¹ Am, ²⁴² Cm, ²⁴³ Cm, ²⁴⁴ Cm)	Infant foods	1	-
	Drinking water		1 Bq/L except for 10Bq/L of ²⁴² Cm and No ²⁴² Pu
	Milk, dairy products		-
	Vegetables	10	-
	Grains		-
	Meat, eggs, fish etc.		-

* Provide guidance so that materials exceeding 100 Bq/kg are not used in milk supplied for use in powdered baby formula or for direct drinking to baby. Source: MHLW(2011), No. 0317 Article 3 of the Department of Food Safety 17.March 2011

Sources: MHLW (2011), No. 0317 Article 3 of the Department of Food Safety 17.March 2011.URL:<http://www.mhlw.go.jp/stf/houdou/2r9852000001558e-img/2r98520000015av4.pdf>; Japan Water Works Association. 2008. WHO Guidelines for drinking-water quality. Third edition. Japan Water Works Association, pp. 203-204. See http://whqlibdoc.who.int/publications/2004/9241546387_jpn.pdf

The European Committee on Radiation Risk (ECRR), consisting of scientists and risk specialists from countries in Europe but taking evidence and advice from scientists and experts globally, had earlier criticized the model of ICRP. Instead of the ICRP model, the ECRR published (2003) *Recommendations of the European Committee on Radiation Risk: Regulators' Edition: Health Effects of Exposure to Ionizing Radiation at Low Doses for Radiation Protection Purposes*. This presents a new framework for analysis of

the mechanism of radiation at the level of the living cell and observation of disease in exposed populations.

WHO (2002b) published several tables (see Tables 6,7,8) as guidelines for radiation emergencies.⁶⁰ At first, for explanation of Table 6, WHO noted, *“Intervention levels in emergency exposure situations are expressed in terms of avertable dose, i.e. a protective action is indicated if the dose that can be averted is greater than the corresponding dose for the intervention level. Standard dose values have been developed by IAEA, and these can help set dose levels for emergency exposures.”*

Table 6: Recommended generic intervention levels for urgent protective measures (WHO, 2002b)

Protective action	Generic intervention level (dose avertable by the protective action)
Sheltering	10mSv in a period of no more than two days
Temporary evacuation	50mSv in a period of no more than one week
Iodine prophylaxis	100mSv (absorbed dose due to radioiodine) ¹

¹ For Children, WHO recommends 10mSv.

As explanation of Table 7, WHO noted, *“Optimized generic avertable doses recommended for temporary relocation and permanent resettlement interventions are given in Table 7. The avertable dose levels apply to situations where alternative food supplies are readily available. If food supplies are scarce, higher avertable doses may apply.”*

Table 7: Recommended generic avertable doses for temporary relocation and permanent resettlement interventions (WHO, 2002b)

Action	Generic intervention level (dose avertable by the protective action)
Initiating temporary relocation	30mSv in a month
Terminating temporary relocation	10mSv in a month
Permanent relocation	1Sv in a lifetime

Table 8: Generic action levels for foodstuffs (Bq/kg) (WHO, 2002b)

Radionuclides	Food for general consumption ¹ (kBq/kg)	Milk and infant foods drinking water(kBq/kg)
¹³⁴ Cs, ¹³⁷ Cs, ¹⁰³ Ru	1000	1000
¹⁰⁶ Ru, ⁸⁹ Sr	1000	1000
¹³¹ I	1000	100
⁹⁰ Sr	100	100
²⁴¹ Am, ²³⁸ Pu, ²³⁹ Pu	10	1

60 WHO. 2002b. ANNEX 4 International and national actions in response to a radiation emergency.

We can see that ICRP actually shows stricter standard than WHO for protective action. Regarding Table 8, WHO noted “this is based on, and consistent with, the Codex Alimentarius Commission’s guideline levels for radionuclides in food moving in international trade following accidental contamination, but it is limited to the nuclides usually considered relevant to emergency exposure situations.” The Codex Alimentarius Commission was created in 1963 by FAO and WHO to develop food standards, guidelines and related texts such as codes of practice under the Joint FAO/WHO Food Standards Programme.

Although WHO has stricter standards than the Japanese government about radioactive iodine, the Japanese government (Table 5) shows stricter standard than WHO about radioactive cesium.

North and east areas from Fukushima Daiichi in Japan are polluted by ^{131}I and ^{137}Cs (See Figure 13). The standards accepted for exposure have significant implications for future accidents, around the world. Most areas in Japan are within a 200km zone from nuclear plants. However, coming back to the current ongoing issues of Fukushima, when we take in consideration the soil pollution by various nuclear species with long half lives, the fact that TEPCO cannot still 6 months after the accident recover the cooling systems properly, and restore facilities of Fukushima Daiichi, it shows a high possibility that tentative standard concerning urgent measures becomes permanent standard by continuous high radiation leak. In the Chernobyl case the standards were applied for many years. Some have even predicted leakage of high temperature core material could eventually reach ground water causing an explosion, if the leakage from the cracks in containment is not fixed soon enough.

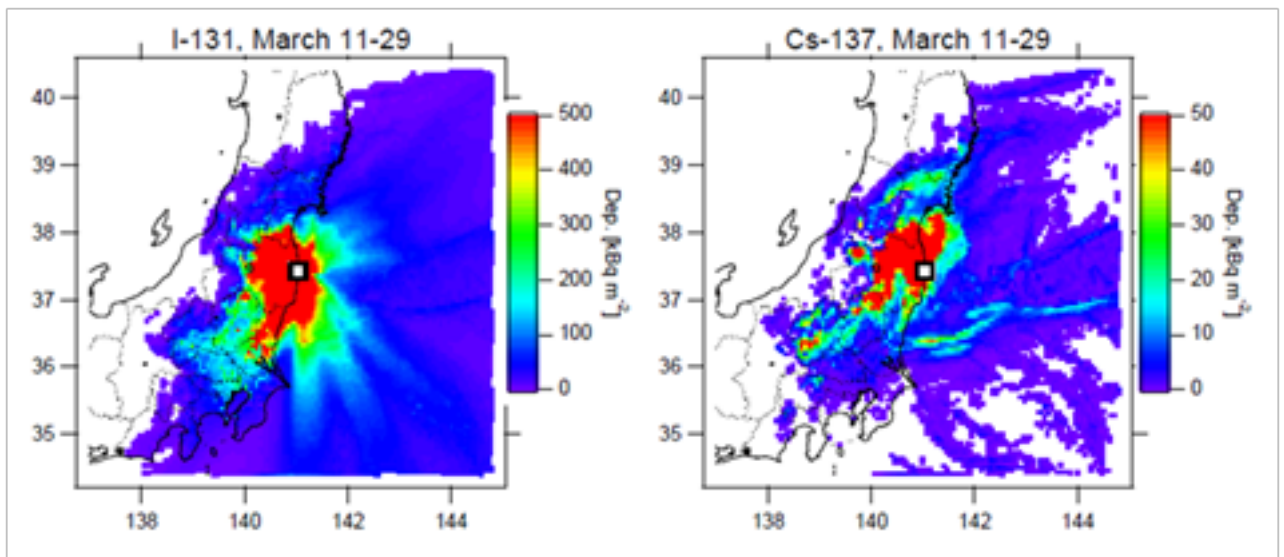


Figure 13: Estimation of integrated deposition amount of ^{131}I and ^{137}Cs by Fukushima disaster

Source: National Institute for Environmental Studies. 2011. Atmospheric behavior, deposition, and budget of radioactive materials from the Fukushima Daiichi nuclear power plant in March 2011. Accessed on 25 August 2011, <http://www.nies.go.jp/whatsnew/2011/20110825/20110825.html>

3.5. Public Access to Data

One of the significant ethical issues in both Chernobyl and Fukushima is that authorities withheld data from the public, both the local community and the wider national and international communities. Although the Chernobyl incident occurred in 1986 during the time that information in the Soviet Union (USSR) was often withheld from the public, the Fukushima incident occurred in 2011, after many international principles had been agreed to open information to the public. The right to information will be further discussed in chapter 5 of this report.

The Soviet government didn't publish the fact that an explosion had occurred on the 26 April 1986, the day of the explosion. Only after the Forsmark NPP in Sweden announced it had measured radioactive material released by the explosion on 27 April 1986, did the Soviet government publish the fact of the explosion to the general public, and later promoted evacuation of over one hundred thousand people.

The Japanese explosions were on video footage and published on the news media, but the details of what happened and release of data for all radioisotopes was delayed. There have also been accusations that TEPCO and the Japanese government did not publish all the data, neither did the meteorological agency permit daily news presentations of the dispersal of isotopes through wind flow. There is a Japanese and English website with a series of press releases from 11 March 2011 provided by TEPCO,⁶¹ and information on the Ministry of Education, Culture and Science (MEXT) website.

The Meteorological Society of Japan forbade members from publicising weather predictions on the spread of radiation.⁶²

The Society published order that members should follow information of predictions by MEXT and governmental agencies on 18 March 2011. Although the general public in Japan can read daily predictions concerning spread of cedar pollen in the air there was a time when data on prediction of spread of radiation appears to have been suppressed. The German National Meteorological Service published predictions concerning spread of radiation by Fukushima. Actually the Japan Meteorological Agency supplied prediction data on the spread of radiation to IAEA 1 or 2 times per day after 11 March as a requirement of IAEA, but delayed publishing data to the public in Japan "to avoid a panic". The analysis called SPEEDI was released to the public on 23 March 2011, but did not become regular until 3 May 2011. We can observe spread of radiation for March 11-29 on 2011 (Figure 10).⁶³

On 29 March a release to the diplomatic community in Tokyo was "Provided information on the detection of plutonium in the soil of the Fukushima Daiichi Nuclear Power Station." (Japan, 2011), however, the other reports are that the ²³⁹Ne and ²³⁹Pu was found over a mile away from the power plant which indicates parts of fuel rods had been exploded out of the NPP. In addition the MEXT allegedly forbade some independent university researchers to publish their own data on radioactive fallout, which raised questions about the control of information in a democratic country.

61 <http://www.tepco.co.jp/en/nu/fukushima-np/index-e.html>

62 Asahi Newspaper, 2 April 2011.

63 National Institute for Environmental Studies. 2011. Atmospheric behavior, deposition, and budget of radioactive materials from the Fukushima Daiichi nuclear power plant in March 2011. Accessed on 25 August 2011, See <http://www.nies.go.jp/whatsnew/2011/20110825/20110825.html>

There are a number of ethical issues, but the right to self-determination based on correct information and data is a principle of modern society, and these accidents in 1986 and 2011 show that it is still not being respected. The principle of non-maleficence is the reason to protect people from dangers of radioactivity, and in both cases eventually over one hundred thousand people were evacuated. If the same standards had been applied in Japan as in Chernobyl, more persons would have been evacuated.

Scientists in Japan are opposed to each other with differing opinions about radiation exposure. This concept of safety or damage and risk links to not only compensation for damage and information disclosure, but also economic policy and energy policy in Japan. Fukushima NPP is located a distance of 250km from the capital city that it provides electricity to. The radiation leaking from reactors of Fukushima NPP will remain over a long period, raising the possibility that the serious pollution of radiation will influence the Japanese social system and communities for decades.

There is a history of nuclear incidents before Fukushima in Japan which have eroded trust that people have. On 8 December 1995, a prototype fast breeder reactor, Monju, located in Tsuruga City, 350km west of Tokyo, was operating at 40% power. The Power Reactor and Nuclear Fuel Development Corp (PNC), a government controlled organization, operated this reactor. At 7.47 pm a high temperature liquid sodium coolant at one of the three secondary heat exchangers started leaking through a broken thermometer sheath on the piping and ignited on contact with air. Primary heat exchangers are designed to take heat out of the core of the reactor to the secondary heat exchangers, which then transfers the heat to steam generators for power. This was a simple fire caused by the leakage of chemically reactive but *non-radioactive* sodium coolant. However due to the delay in shutting down the reactor, 640kg of the sodium leaked in 3 hours and caused some unexpected damage due to the fire and chemical reactions with the surrounding structure. The sheath was found to have been broken due to design errors such as stress concentration and breakage, mechanical faults, and an engineering design failure to consider the fact that liquid sodium is 120 times more heat conductive than water.

Despite repeated requests from neighbours and other anti-nuclear agencies, the PNC affirmed that the power plant was absolutely safe to operate. Edited videotapes taken at the site were later allowed for public viewing. The PNC's delay (of about one hour) in informing the neighbouring community and other agencies of the accident also sparked a fierce protest by the public, who had been suspicious from the beginning.

In the case of the Tokaimura accident on 30 September 1999 (level 4 on the INES Scale), three workers received lethal doses and died as a result of the accident, despite advanced medical treatment and attempts to save them. It is 140km north of Tokyo. A total of 119 people received a radiation dose over 1 mSv from the accident. There was localised evacuation of some households and others were told to stay inside until it was safe. The cause of the accident was workers mixing too much uranium containing water into buckets, reaching a critical level for a chain reaction to start, and giving the lethal dose to those three. They had not been trained well, and the IAEA report placed the blame on "human error and serious breaches of safety principles".

The most expensive of plants besides Fukushima is a fast breeder reactor called Monju in

Fukui prefecture. The total money from 1980 to 2011 for Monju was 948.1 billion JPY (USD 12 billion). Of this JPY 589 billion was for building (1980-1994), of which the government spent JPY 450 billion. Operation costs have been JPY 360 billion (government funds). For the 2011 budget alone it is JPY 22 billion including 18 billion for maintenance and 3 billion for checking.⁶⁴ It does not produce electricity but is costing money to cool the core. The costs of the new shelter are only a small fraction of the total costs however, which are in hundreds of billions of dollars.

The above incidents show the importance of sound ethical practice by decision makers and engineers working in a nuclear plant facility. Design errors and cheap components arise from the lack of competence on the part of the engineers attributable to the cheap labour employed by power plant owners to save money. Secondly, the cover up of information and the delay in reporting a nuclear accident, regardless of its magnitude goes against the basic ethical principle of moral theory and the obligation to fulfil one's right to knowledge.

The failure of the officials to fully inform the public, and also to forbid some data from being made available, caused further loss of faith in the public. The government was vague in announcements by not confirming meltdowns when circumstantial evidence indicated they had occurred. Providing information to the public could have lowered cancer risk for persons exposed both in the residential area as well as wider consumers. The public is even more critical about Fukushima in light of these previous incidents, because the companies involved and the government had promised to be open the next time. The public in Japan is also critical of the mainstream mass media that limits publication of articles against nuclear energy because it is the leading source of advertising revenue. This history of attempting to cover-up accidents is not only in Japan, but globally, and thus had contributed to the fall in public support (See section 5.1).

64 <http://www.jaea.go.jp/english/index.shtml>

4. Economics of Nuclear Energy Technology

4.1. Feasibility of Nuclear Energy

There are various economic and financial forecasts regarding the cost of different energy sources. Often, these comparisons include traditional fossil fuels, such as oil and gas with hydropower and nuclear, for instance. More recently, many calculations including solar, wind, geothermal, and other sources have been published. Equally important as the calculation themselves are the assumptions under which they are made, as many of these raise ethical issues. While there are many accusations of “hidden costs” in nuclear energy, such as the cost of decommissioning plants and insurance guarantees, this depends on what these terms mean, or what “total costs” actually include. Nuclear energy production might constitute such considerations, as well as any non-monetary “safety” costs and environmental costs. The bulk of the costs associated with nuclear energy lie with the fuel, which includes mining of Uranium ore, the conversion and enrichment of ^{235}U and its fabrication into fuel assemblies. However, one cannot ignore the significant costs involved in nuclear waste management and its ultimate disposal that have major consequences on the society and environment. One may also need to include the substantial investments made in basic and applied research in nuclear technology, at least in comparison with other energy technologies.

As discussed in section 1.3, nuclear energy is relatively carbon-free,⁶⁵ when viewed as a capital-intensive undertaking, despite its standard long construction periods. The competitiveness of a NPP depends on the economic and investment conditions of a country. In present times, the proportion of the total lifetime capital investment for a nuclear facility is approximately 60% of the lifetime generation costs, with fuel costs at 20%, operation and maintenance (O and M) making up the remaining 20%.⁶⁶ In comparison, the capital requirements to build a fossil fuel plant can be significantly lower with fuel making up a major portion of the lifetime capital costs- 70% for natural gas and some 50% for coal. In order to accurately compare the cost of nuclear energy with other renewable sources, it is imperative to consider the assumptions and costs in greater detail.

This chapter examines in particular the economic issues, but does not negate the importance of other factors in ethical policy making. Even sources such as solar and

65 Natural Resources Defense Council, Feb 2007. *Sustainable Development and Nuclear power*. IAEA Publication. There are no particulates released or emission of greenhouse gases during the actual operation of a nuclear power plant. However the use of fossil fuels at other stages of the nuclear energy chain (such as uranium mining and transportation) might result in some emissions that would have to be factored in a “full chain energy” assessment. Fossil fuel plants produce significant quantities of toxic pollutants and waste. For instance, a 1000MW (e) coal plant without abatement technology annually produces an average of 44,000 tonnes of sulphur dioxides and 22,000 tonnes of nitrous oxides into the atmosphere. With modern abatement technology, there is a ten-fold reduction in noxious gases but nevertheless about 500,000 tonnes of solid wastes are produced. In contrast, a nuclear plant of similar power generating capacity, about 30 tonnes of high level radioactive wastes along with 800 tonnes of low to intermediate radioactivity are discharged annually. It is expected that innovative actinide burning reactors in future may be able to transmute long-lived radioactive species to short lived ones.

66 IAEA. 2010. *Sustainable Development and Nuclear Power*, See <http://www.iaea.org/Publications/Booklets/Development/index.html>

wind energy that are considered “Green” have hidden costs. For instance, wind turbines can kill birds and bats. It is estimated that about 100,000 birds are killed each year in the United States from wind turbines, and if wind power increases to 20 percent of electricity, the number of bird kills will increase 30 times (Cohn, 2008). Although this is a smaller number in comparison to other sources of inadvertent bird deaths (e.g. from communication towers), it still represents a significant concern. Hydroelectric dams may release more GHG emissions (taking into account the construction phase) than many coal plants (see for example: Beam, 2005), although actual comparisons are not conclusive, and the longer a dam operates the more favourable it will be compared to fossil fuel plants. The same is true for the GHG emissions from construction of nuclear plants and mining of ore as discussed below in detail.

Electricity produced from NPPs can be controlled to a set level, unlike wind and solar energy, which require upgraded electrical grids, as they are intermittent power sources. The current generation of electrical grids has inefficient high-voltage long-distance transmission lines, may not be able to deal effectively with demand and supply effectively, and have outdated monitoring and control technology (see for instance, Hendricks, 2009). There is research on the manner in which solar and wind energy production facilities can effectively integrate with grids at high capacity levels (Winters, 2009), compared to nuclear, for example.

The producers of NPPs established the World Nuclear Association (WNA), firstly as the Uranium Institute in London in 1975 for promotion of nuclear power by peaceful utilization of Uranium, analysis and collection of information concerning atomic industry as well as information exchange and transmission of information. Over 100 corporations, associations, and research institutions from 32 nations are members of WNA. The global strategy in WNA is the global development of NPPs in the world for the future. The World Nuclear Association (WNA, 2011) showed nuclear electricity generation at 13.8% of electricity generation in the world as of 1 April 2011. The WNA (2009f)’s Nuclear Century Outlook is a long-term projection designed to gauge the prospects for the worldwide growth of nuclear power in the 21st Century. There is a global policy for promotion and sales of NPPs by cooperation between states, corporations and international agencies like IAEA and WNA. WNA designed plans of both low projection and high projection with many nations as concrete sales target. WNA analyzes information concerning national energy plan of each nation for its global strategy of sales promotion.⁶⁷

To arrive at sound decisions regarding energy policies in any country, policy makers need to make monetary comparisons of the costs and benefits of different types of power generating sources, taking into account the full range of research evidence and ethical assumptions that are implicit in choice of any technology that has potential and actual environmental consequences.

67 WNA(2011), “WNA Nuclear Century Outlook Data, See : http://www.world-nuclear.org/outlook/nuclear_century_outlook.html

4.2 Nuclear fuel costs

Fuel cost essentially takes into consideration the annual “burn-up” of nuclear fuel during reactor operation. The inclination towards harnessing nuclear energy is its seemingly low fuel prices as compared to fossil fuels, and includes the cost of purchasing uranium, its conversion, enrichment and fabrication. Additional costs are also incurred due to transportation, storage and inventory charges. For a 1000 MWe BWR or PWR based on an eighteen-month fuel cycle, the approximate cost of one reload (defined as replacing one-third of the core) is about USD 40 million. Thus, the average fuel cost at a nuclear facility in 2009 was 0.57c/kWh (WNA, 2010). Since nuclear plants refuel every 18-24 months, they are not affected by short term fluctuating uranium prices, unlike fossil fuel plants (Nuclear Energy Institute). Moreover, fuel costs constitute only 28% of the overall production costs while for fossil fuel plants they make up about 80% of the total cost.

Table 8. Approximate expenses (USD) associated with different stages of Uranium processing

Processing costs	Cost involved	Total cost
Uranium mining:	8.9 kg U_3O_8 x \$115.50	1028
Conversion:	7.5 kg U x \$12	90
Enrichment:	7.3 SWU x \$164	1197
Fuel fabrication (UO_2):	Per kilogram	240
Total, approx:		2555

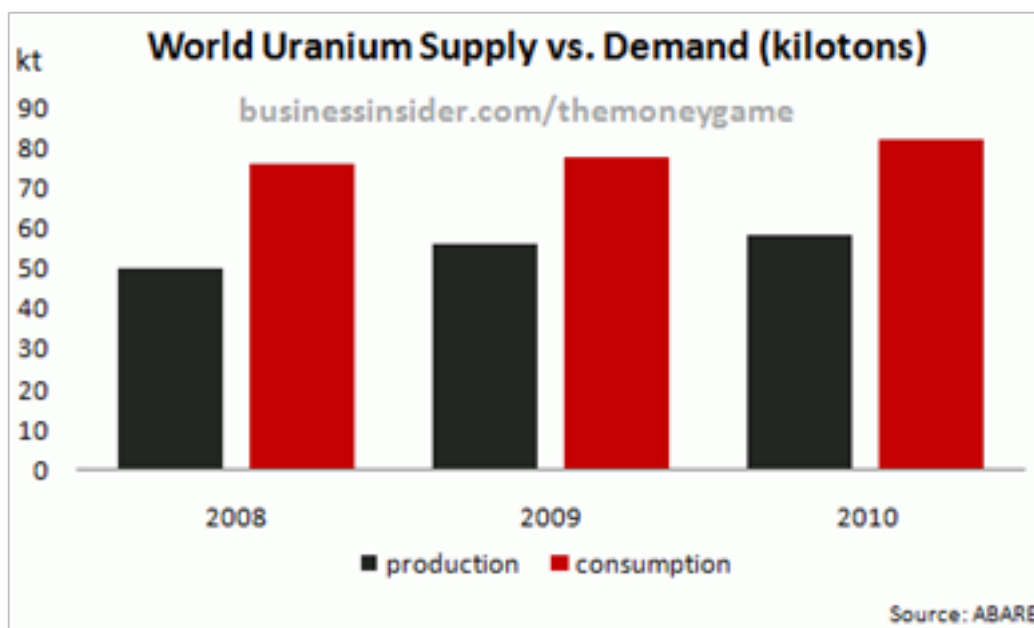


Figure 14: Global uranium production and demand

A recent study by AREVA in 2008, suggested that 17% of the total kWh generation cost for its EPR (European pressurized reactor) was fuel costs (WNA 2010b). The cost break down was shown to be 51% natural uranium, 3% conversion, 32% enrichment and 14% fuel fabrication. In January 2010, the approximate US dollar cost to get 1 kg of uranium as UO_2 reactor fuel (at likely contract price for the natural uranium from a mine) was as shown in Table 8 (WNA, 2010b). Fissionable isotopes like ^{235}U are high energy

density fuels and owing to the small quantities needed⁶⁸ (IAEA, 2010; WNA 2010b), the environmental impact with regards to its extraction, transport requirements and quantities of environmental wastes released are also diminished.

In light of the above cost analysis, it can still be said that the total fuel costs of a NPP in the OECD, for example, are one third of a coal-fired plant with a similar electricity generating capacity, and between a quarter and fifth of those for a gas combined-cycle plant. In recent times, the efficient use of fuel and newer methods of reprocessing spent fuel have led to a decrease in the overall fuel cost. This was indicated in Spain, where the nuclear electricity cost was reduced by 29% over 1995-2001 as a result of boosting enrichment levels and burn-up to reach a 40% fuel cost reduction (WNA, 2010b). The World Nuclear Association predicts that uranium mining will need to increase by almost 300% in the next 2 decades to meet the world's energy demands (WNA, 2006). Data in Figure 14 indicate that the demand (consumption) for uranium since 2006 has far exceeded the supply and forecasts an increase by about 22% in 2010 with an expected increase of 3.7% per year to 2030 (ABARE). Moreover, the global need to be less dependent on fossil fuels coupled with economic growth in countries like China and India gives an impetus to invest heavily in nuclear energy due to which both demand and price of uranium will be expected to rise (IAEA, 2009). Conversely, the decline in global economy in recent years has also led to a drop in uranium fuel prices from USD 130 per pound (July 2007) to USD 45 per pound (October 2008) (U_xC: The Uranium nuclear fuel price indicators) due to steady depletion of uranium reserves. At present, known uranium reserves worldwide are expected to last for another 30 years although, uranium extraction from oceans is a proposed long-term solution for the impending uranium shortage (Energy Watch Group). However, apart from the questions on the feasibility, such a project could send uranium prices soaring in the future because of higher mining costs. In the long term, it is expected that the implementation of carbon taxes and carbon trading scheme will give a new thrust to existing NPPs due to their low running costs so that they compete favourably with fossil fuel plants.

4.3 Operation and Maintenance (O and M) of Nuclear Power Plants

Operation and maintenance costs include the cost of running and maintaining the power plant for the period of its lifetime. Allowance has to be also made for expenses related to labour, material and supplies, contractor services, licensing fees and other incidentals such as employee expenses and regulatory fees. As nuclear industries adopt a more global co-operative approach, mass production of nuclear plants will supposedly bring costs down (WNA, 2010b).

Uranium is a highly concentrated source of energy and easily transportable. One kilogram of fissionable uranium will yield about 20,000 times as much energy as the same amount of coal. Another advantage of using uranium over fossil fuels is the

68 High energy density fuels are normally used in small quantities to produce a large amount of energy. Hence, 1kg each of coal, oil and nuclear fuel generate 3 kW.h, 4 kW.h and 50, 000 kW.h of electricity, respectively (IAEA: Sustainable development and nuclear power).

low impact that it will have on the overall electricity cost. For example, a doubling of the uranium market price would increase the fuel cost of a light water reactor by 26%, and the electricity cost by 7%.⁶⁹ The use of alternate fission fuels (^{238}U , ^{239}Pu and thorium) have been considered in recent times by developing fast breeder reactors (FBR). However, apart from being an expensive mode of generating electricity (80% higher), it is feared that the high amounts of plutonium produced could be potentially used for non-civilian purposes.⁷⁰

Most (fast) breeder reactor plants have either suspended or ceased their activities due to uncontrollable fission reactions, financial liabilities and safety issues like the risk of catastrophic accidents.⁷¹ From an economic aspect, a report published by the National Academy of Sciences of the United States (NAS) on the feasibility of plutonium reactors suggested that the cost of processing and fabricating uranium oxide fuel (MOX (mixed oxide) at 4.4% enrichment) at about 1400 US dollars in 1992 assuming a natural uranium price of US dollars 55 per kilogram. The cost of MOX fuel fabrication assuming the cost of plutonium is free (obtained in surplus from nuclear weapons) would be 1900 per kilogram in 1992 dollars (excluding taxes and insurance). The higher cost of MOX as compared to uranium would not only increase the overall annual fuel costs but also translate to a higher cost of reprocessing spent MOX. This is because it will be more radioactive than uranium spent fuel due to higher plutonium content. The question of liability and insurance is discussed in section 4.5.

4.4 Capital costs

The factors that account for the “total capital cost” for a nuclear plant includes many components such as “overnight plant construction cost”⁷², the owner’s cost and other associated expenses such as capital cost, escalating construction costs (including site works, switch works and so on) over the time period of construction. In recent times, a number of capital cost estimates from different sources have been published ranging from a conservative approach to total capital estimates incorporating escalations due to factors such as construction delays, material cost fluctuations and capital cost for funds and so on (see Craig, 2009).

69 Fast Breeder Reactors (FBR) operate on the principle that ^{238}U , by neutron capture, converts to Plutonium (Pu) that can be subsequently reprocessed and used as reactor fuel. Neutrons are cooled by liquid sodium as the moderator (instead of water or helium) and hence have high thermal energy.

Excess plutonium produced leads to problems of reprocessing and also generates large amounts of radioactive wastes- an uneconomical situation coupled with the likelihood of misuse for making weapons-grade plutonium in countries with a prolific nuclear program.

70 Plutonium as a fuel is being considered for use in FBR’s or in Generation IV reactors and currently being utilized in USA, Japan and France. The Generation IV International Forum (GIF) addresses non-proliferation by utilising a closed-fuel cycle FBR to minimise high-level wastes. Plutonium is generated in the core where the burn-up is high as well as the proportion of other plutonium isotopes besides ^{239}Pu remains high. Mixed oxide fuel (MOX) is a combination of weapons grade Pu with uranium to render Pu to “reactor grade” fuel. A process adopted by USA and Russia to convert their weapons stock-pile innocuous. See *Scientific American*, 19 February 2010.

71 Another alternate reactor fuel source is to convert non-fissile thorium-232 into uranium 233. However, this breeder technology is still being researched by many countries (IEER, Energy and Security) especially India.

72 Overnight construction costs refer to the cost incurred if the power plant could be built at “today’s prices” or literally “overnight”. This cost does not include financing charges during construction (since the plant is built “overnight”) and inflation rates. Overnight construction costs are different from total capital costs.

Usually, the economic assessment for funding a NPP construction is done by using a levelized energy cost (LEC) approach which is the average cost of producing electricity over the plant's life-time. This includes initial investments, operation and maintenance (O and M), cost of fuel as well as costs of waste disposal and plant decommissioning. While a number of factors (costs of government subsidies, costs of public health and environmental impact and so on), known as "boundaries" have to be considered while calculating the LEC, the most important is the discount rate. The value of the discount rate chosen can often affect the results one way or another and depends on the cost of the initial capital.⁷³ Hence, the economic competitiveness of a nuclear plant depends on the investment conditions as well as the interest and payback period of loans. In the present day competitive and liberalized markets, initial capital investments have to be recovered in a relatively short period of time at high discount (interest) rates. For discount rates of 5%, nuclear power has been competitive with fossil fuels, while at higher discount rates of 10%, it is difficult to compete with coal and gas fired plants.⁷⁴

A 2010 OECD publication, *Projected Costs of Generating Electricity*, compared 2009 data for generating base-load electricity with estimates for 2015 as well as the costs of power from renewable sources. The data showed that nuclear power was very competitive at USD30 per tonne with low discount rates of both 5% and 10% (Tables 10-11). The study used average life-time costs and includes average costs of producing electricity as well as capital, finance, owners cost on site, fuel and operation over a plant's life-time and provision for decommissioning and waste disposal.

It was further shown that at 10% discount rate⁷⁵, nuclear energy is still cheaper in all of the listed countries, but in Belgium, Czech Republic and Netherlands gas becomes cheaper than coal (Table 10).⁷⁶ Detailed studies regarding the economic viability of nuclear power have been undertaken in many European countries (WNA, 2010).

Based on these studies, data on the projected costs from different energy sources were published as shown in Table 11. Given the fact that financing costs and construction of a nuclear power plant are relatively high due to the need to incorporate special materials, innovative safety features, and state-of-the-art features the cost of fuel is much lower.

A cost study of existing energy technologies was undertaken by the IEA/NEA to understand the factors affecting the economics of electricity generation (IEA/NEA

73 Based on the "time-value" of money, the discount rate defines the present value of a future payment P. For example at 10% discount rate, payment P, expected in 15 years has a present value of $P \times 1.10 \times 10^{-15} = 0.24P$.

74 IAEA. 2010. Sustainable Development and Nuclear Power, See <http://www.iaea.org/Publications/Booklets/Development/index.html>

75 At a 10% discount rate, this study found that nuclear energy was still cheaper than coal and gas except in Belgium, Czech R and Netherlands where gas is cheaper. Coal with carbon capture (CCGT) was more expensive than nuclear power.

76 Future competitiveness of nuclear power will depend on its virtue of being relatively carbon-free while additional costs may be loaded onto coal and gas-fired plants in the form of CO₂-capture as well as expenses incurred due to the quenching of methane and noxious gases (sulphur dioxide and nitrogen oxides). In terms of equivalent grams of carbon emissions per kilowatt hour, gas plants are on par with coal plants. For fossil fuels, indirect costs such as waste management and plant decommissioning are not included into the electricity cost.

executive Summary). Cost data was collected from more than 130 power plants and also includes plants that could be decommissioned between 2010 and 2015. Their findings are presented in Table 12.

Coal prices were found to fluctuate widely over the economic lifetime (40 years) of a plant by as much as a factor of 20 (expressed in the same currency) in the year 2010. The study excludes specific costs associated with wind power and the need for back-up power to compensate for low average availability factor. The average levelized costs presented are for 5% discount rates. While it is not possible to generalize the economics of power generation, the levelized costs of power in each country are dependent not only upon financial considerations such as discount rates, but also on fluctuating coal and natural gas prices. Ensuring a steady supply of electricity hence depends on the choice of energy technology selected as well as financial stability of the country, such as costs of raw resources and measures such as the implementation of a carbon-tax. Although the calculations to estimate the true costs of electricity generated from any source are complex, and require various assumptions, it is possible and ethical to develop transparent mechanisms to calculate these costs. The IEA/NEA electricity cost studies are summarised in Figure 15.

Table 10: The OECD electricity generating cost projections for 2010 at 5% discount rate, cents/kWh.

Country	Nuclear	Coal	Coal with CCS	Gas CCGT	Onshore wind
Belgium	6.1	8.2	-	9.0	9.6
Czech R	7.0	8.5-9.5	8.8-9.3	9.2	14.6
France	5.6	-	-	-	14.6
Germany	5.0	7.0-7.9	6.8-8.5	8.5	10.6
Hungary	8.3	-	-	-	-
Japan	5.0	8.8	-	10.5	-
Korea	2.9-3.3	6.6-6.8	-	9.1	-
Netherlands	6.3	12.0	-	7.8	8.6
Slovakia	6.3	12.0	-	-	-
Switzerland	5.5-7.8	-	-	9.4	16.3
USA	4.9	7.2-7.5	6.8	7.7	4.8
China	3.0-3.6	5.5	-	4.9	5.1-8.9
Russia	4.3	7.5	8.7	7.1	6.3
EPRI (USA)	4.8	7.2	-	7.9	6.2
Eurelectric	6.0	6.3-7.4	7.5	8.6	11.3

For China and Russia a carbon emission cost of 2.5 cents /kWh is added to coal and 1.3 cents /kWh to gas to ensure a sound comparison with data in other fuel/technology categories.

Table 11: Cost comparison from alternate energy sources in EU at 10% discount rate

Energy Source	2005	Projected 2030 with EUR 20-30/t CO2 cost
Gas CCGT	3.4-4.5	4.0-5.5
Coal - pulverized	3.0-4.0	4.5-6.0
Coal - fluidized bed	3.5-4.5	5.0-6.5
Coal IGCC	4.0-5.0	5.5-7.0
Nuclear	4.0-5.5	4.0-5.5
Wind onshore	3.5-11.0	2.8-8.0
Wind offshore	6.0-15.0	4.0-12.0

Table 12: Cost data comparison for various energy sources.

Energy type	Average time of plant construction (years)	Overnight construction costs* (USD/kWe)	Levelized costs (USD/MWh)
Coal	4	1000-1500	25-50
Gas	2-3	400-800	37-60
Wind	1-2	1000-2000	35-95
Nuclear	4	1000-2000	21-31 (includes refurbishment and decommissioning)

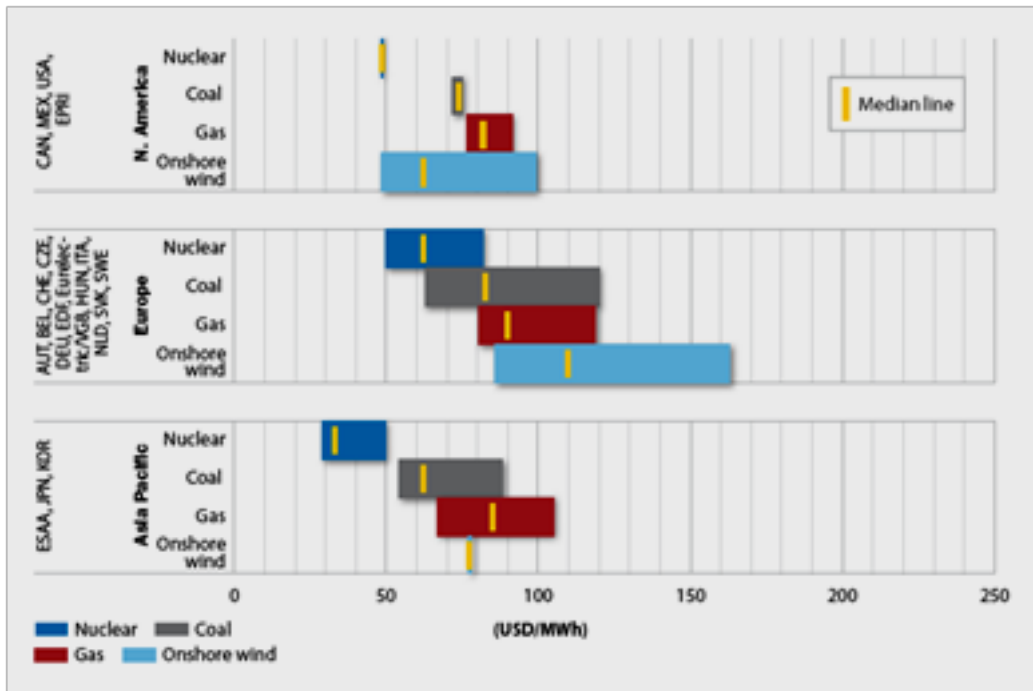


Figure 15: Regional ranges for levelized costs of electricity (LCOE) for coal, natural gas, wind and nuclear power plants at 5% discount rates.

A cost analysis study of the existing energy technologies was also conducted in the UK by PB Power (Royal Academy of Engineering, 2004). Within this study, the actual costs of building, maintaining and running various types of power stations in the UK were considered, and the costs of producing electricity at a discount rate of 7.5% was derived using a common financing model.⁷⁷ The graph in Figure 16 shows the cost of generating electricity from different types of technology currently available in the

⁷⁷ In the study, the cost value includes the capital cost of the power generating plant and equipment, the cost of fuel burning (where applicable) as well as operation and maintenance costs. Decommissioning costs for nuclear power generation are included (internalised) in the capital cost estimate of a nuclear plant

UK. The present-day cost of generating electricity for each source was set at levels considered necessary to provide a dependable power supply.⁷⁸

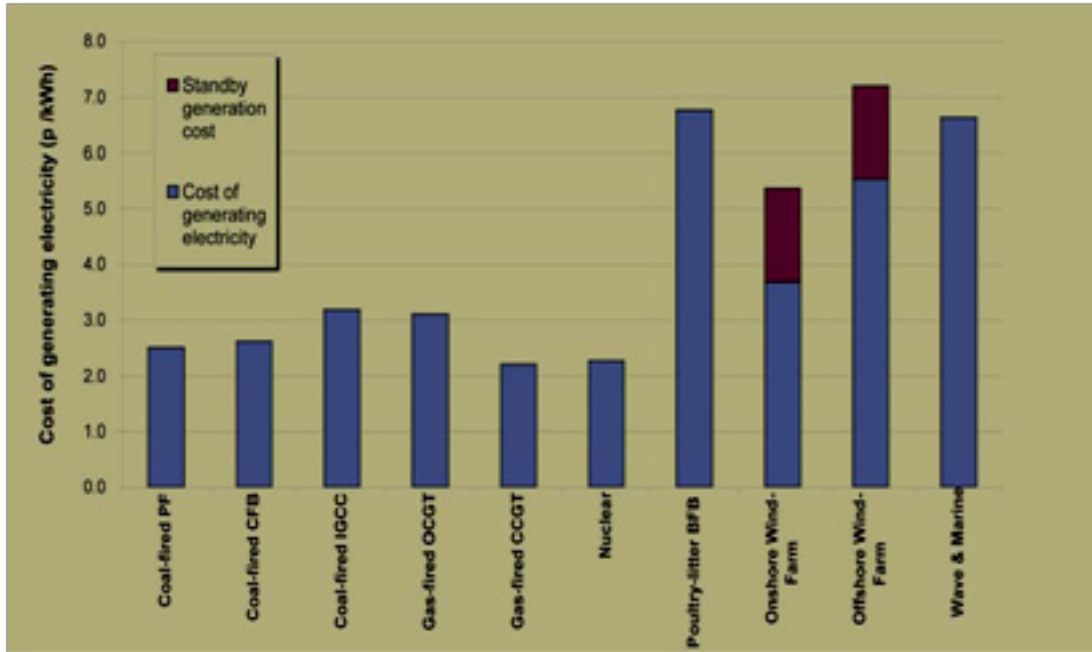


Figure 16: Present-day cost of generating electricity (pence per kWh) with no cost of CO₂ emissions included (The Royal Academy of Engineering, 2004).

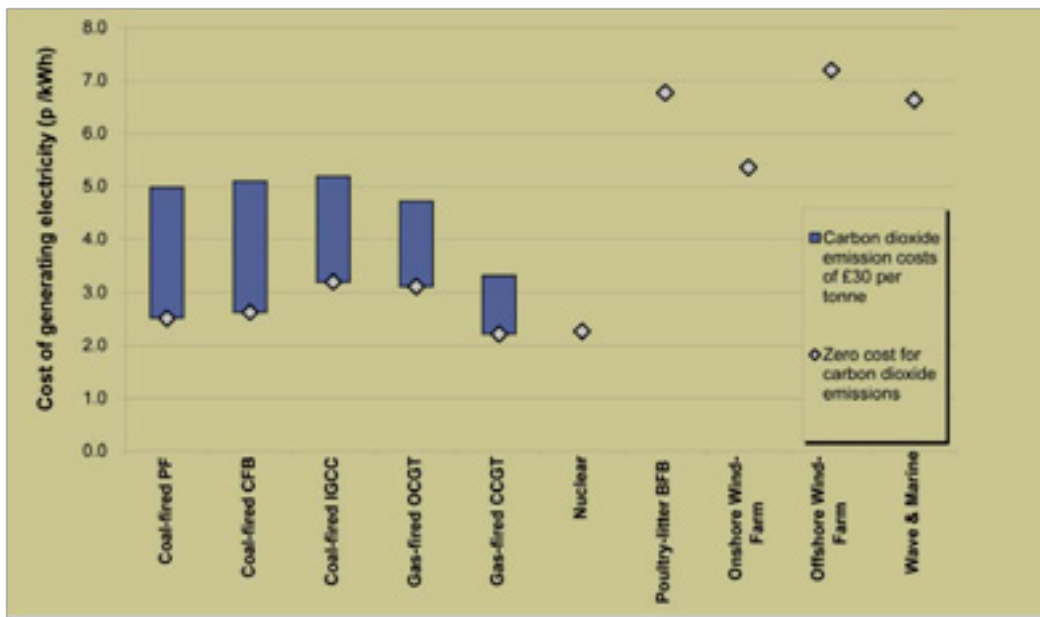


Figure 17: Data illustrating the effect on the cost of generating electricity with respect to CO₂ emission costs (The Royal Academy of Engineering, 2004).

78 For intermittent power generation sources such as Wind and Wave Energy, an additional amount has been included as a provision for standby generation since the generating capacity of these sources may often vary.

Figure 17 illustrates how a fixed carbon dioxide emission (CO₂) allowance will be assigned to new power generation plants for 2005-2007. The cost is calculated on the basis of pounds (£) per tonne of CO₂ released. The values range from 0 - £30 per tonne, wherein the upper limit indicates the cost of carbon dioxide sequestration. The cost of generating nuclear power, which is carbon-free in the operational stage, remains unchanged and hence will become more favourable as the cost of carbon emissions increases. Although this study was conducted in the UK, and thus is applicable to power plants in the UK, it gives an idea of the relative advantages of using renewable energy sources like nuclear power.

An inter-disciplinary MIT case study (NRDC, 2003) titled “*The Future Role of Nuclear Power*” presented an economic comparison of nuclear and fossil-fuel plants in the United States. This study examined the growth of new generation nuclear plants with capacities of 360 GWe⁷⁹, scalable to 1000 GWe by mid-century thereby boosting the approximate 20% nuclear share in electricity generation of the US to about 30% (16% to 20% globally). Some important challenges that were considered for the development of emerging power technologies were cost, safety, waste management, and proliferation risk (for technologies like nuclear power). The study also made recommendations to mitigate heavy monetary costs that will impact the viability and competitiveness of nuclear plants as well as the levying of societal and environmental price of carbon emissions that could improve the competitiveness of nuclear fuel.⁸⁰

Table 13: Data showing levelized cost of electricity generated from a new nuclear plant as compared to coal or gas-fired plants. Source: Interdisciplinary MIT study, NRDC, 2003.

Case (2002 USD)	Real Levelized Cost Cents/kWe-hr
Nuclear(LWR)	6.7
+Reduce construction cost 25%	5.5
+Reduce construction time 5 to 4 years	5.3
+Further reduce O&M to 13 mills/kWe-hr	5.1
+Reduce cost of capital to gas/coal	4.2
Pulverized Coal	4.2
CCGT(low gas prices, \$3.77/MCF)	3.8
CCGT(moderate gas prices, \$4.42/MCF)	4.1
CCGT(high gas prices, \$6.72/MCF)	5.6

a. Gas costs reflect real, levelized acquisition cost per thousand cubic feet (MCF) over the economic life of the project.

The NRDC (2003) study points out that while existing nuclear plants are operating successfully, energy companies are sceptical about investing in new plants because they are uneconomical since electricity markets may well be subject to deregulation in some parts of the world in future. The comparison was based on a model using

79 Large power plants usually have an electrical output capacity of around 1GW; hence abbreviated as GWe. Gigawatt-year (GW(e)-yr) is commonly used in electricity production and 1GW-yr = 8.76x10⁹ kWh. However, a 1GW capacity power plant does not generate 1GW-yr of electricity per year. The ratio of the actual power generated to the amount that could be generated per year if the plant were to operate at full capacity for one year is called the *capacity factor*. Typical power plants operate at a capacity factor of around 60 to 80%

80 Some recommendations offered by the expert panel include: offering limited production tax-credit to “first-movers” who basically are private investors; an incentive extendable to other carbon-free electricity technologies, advancing a U.S Department of Energy (DOE) balanced long-term waste management R&D program, developing alternate carbon-free energy sources and carbon sequestration.

actual parameters than engineering estimates to compare the real cost of electricity from nuclear with pulverized coal and combined natural gas cycle plants over their economic lifetime. They assumed 85% capacity factor and a 40-year economic life for the nuclear plant. From the data shown in Table 13 it is clear that nuclear energy will become competitive as compared to coal and gas-fired plants only if all the cost-improvements for the nuclear plant are realized.

Table 14: Data shows power costs with carbon taxes for Levelised Electricity

Costs (US Cents/kWe-hr)

Cases	\$50/tonne C	\$100/tonne C	\$200/tonne C
Coal	5.4	6.6	9.0
Gas (low)	4.3	4.8	5.9
Gas (moderate)	4.7	5.2	6.2
Gas (high)	6.1	6.7	7.7

Source: Interdisciplinary MIT study, NRDC, 2003.

Based on the values in Table 14, the study indicates that nuclear power does become cheaper if a social cost of carbon emission is internalized by a carbon tax or “cap and trade system”. The emissions costs are in the range of USD 50 – USD 200 per tonne of carbon. The ultimate cost levied depends on the carbon emissions permitted, technology developments and costs involved in the long-term carbon capture and sequestration.

The NRDC (2003) study also pointed out that, “subsidies offered by the United States government in the form of tax-payer dollars to energy companies to “jump-start” their nuclear program with new uneconomic, nuclear plants would do little to mitigate the immediate problem of global energy crisis”. Their proposed solutions to the energy problem that can be generalized to any country, is firstly to discourage tax-subsidies and allow new, innovative energy technologies to compete with existing fossil fuel and nuclear energy programs on a “level playing field”. They advocate the internalization of environmental costs of the technologies considered so that taxpayers are appraised of the true-cost of electric power. A follow-up study in 2009 by the interdisciplinary MIT group behind the the NRDC study further showed that the global need for “clean” power has increased over the past 6 years due partly to rapid growth of economies in India, China and Mexico, and new technology developments like plug-in hybrids that depend on electricity. The need for a mutual decision between countries to adopt policy options to reduce green-house gas emissions has therefore stressed the importance of nuclear power, fossil fuel use deploying carbon capture and sequestration, and to exploring other renewable technologies like wind, hydropower, geothermal and solar as important options for achieving global power equity with low carbon foot-print.

A European Union externality cost study conducted in the Philippines (Greenpeace Southeast Asia Study, 2003) noted the high external costs of coal-fired plants as opposed to wind and solar power. The study dismissed the fact that “cheap coal” was a myth and urged that external factors such as environment and human life-styles have to be accounted for before embarking on new coal-fired plants. As mentioned before, while nuclear plants involve high initial cost, fossil fuel plants have high fuel expenses

and serious socio-environmental consequences.⁸¹

The speculations about the cost-effectiveness of nuclear power programs in the future was highlighted in a recent Nuclear Energy Institute study (NEI, 2010) that indicated projected expenses involved in the construction of new nuclear plants in the United States. The proposed estimates range from USD 4 billion for a single plant to USD 18 billion (2010 US dollar rate) for a two-unit plant and includes the cost of engineering-procurement and construction (EPC) costs, transmission lines and other services. This wide variation in capital costs was attributed to factors such as: uncertainty in the escalation of commodity prices, use of different financial assumptions depending on the year (inflation or escalation) in which the costs are projected as well as estimates including comparisons between different power generating technologies. Independent cost analyses of new power generating plants have been undertaken by several academic institutions, research organizations and government agencies have found that future nuclear power plants will be competitive with traditional fossil fuel plants. The findings of one such company namely, the Brattle Group, under contract to Connecticut Light and Power and United Illuminating Inc. is presented in Table 15 (NEI, 2009).

Table 15: Capital Cost Analysis (2008 USD) of new power generating companies by Brattle Group (NEI, 2009).

	Nuclear	SCPC	SCPC/wCCS	IGCC	IGCCw/CCS	Gas CC	Gas CC w/CCS
Capital Cost (\$/kWe)	4,038	2,214	4,037	2,567	3,387	869	1,558
Levelized Cost (\$/MWh)	83.40	86.50	141.90	92.20	124.50	76	103.10
SCPC = supercritical pulverized coal; CCS = carbon capture and storage; IGCE = intergrated gasification combined cycle; CC = combine cycle							

Although nuclear plants had the highest initial capital costs, the levelized costs are the lowest except in the case of Combined Cycle (CCG) gas plants (USD 7.14 per mmBtu, 2008 dollars) without carbon-capture. Additional analyses assuming different gas price scenarios, carbon tax prices and technology costs also resulted in nuclear technology being the most cost effective. Further information regarding cost analyses studies of new power generating plants can be found in the Nuclear Energy Institute (NEI, 2009) document.

Despite having some definite cost advantages over traditional fuel technologies,

81 An externality study conducted by the European Commission in 2003 with different types of power generation and coal-fired plants in Philippines demonstrated the detrimental effect of coal burning on human mortality, human morbidity as well as bio-diversity due to hazardous toxic emissions. While condemning the proposed development of future coal-fired plants, the study revealed that alternate energy sources like Wind, Solar Power and Biomass should account for 10% of the country's power capacity as the most economical way of power generation.

nuclear power comes with inherent problems such as proliferation, reactor safety and waste disposal. Countries need to address these pressing issues from an ethical and human rights standpoint before committing to nuclear power in the long term.

4.5. Externalities: The “Hidden Costs”

Some of the most significant impediments to nuclear energy becoming a sustainable, safe source of power are the “unseen” expenses that lead to speculations about the actual costs of nuclear energy. Though some scientists and advocates of nuclear power turn a “blind eye”, the potential long-term viability of nuclear power could decrease if financial and environmental risks are ignored. While the financial costs associated with different stages of the nuclear plant were discussed in the previous sections, nuclear power is inherently tied to “external costs and benefits”, termed as “externalities”. Liabilities include the cost of environmental damage, adverse radiation effects on human health following a nuclear accident, damage to human health during routine operation of nuclear facilities, and the long-term problems associated with nuclear waste disposal and plant decommissioning (Externe, MEC publications).

According to holistic socio-economic welfare analysis, policies should ensure that prices reflect the total costs of electricity by incorporating taxes, subsidies and other socio-economic cost factors. This internalization of external costs is intended to bring the social and environmental variables and the economic aspects on an even page. The classification of what to consider from a cost perspective however requires a number of ethical assumptions.

To internalize electricity costs, which are usually busbar costs,⁸² socio-environment damages need to be identified, estimated and assigned a financial value. When such variables are factored into the price of electricity, the actual cost of any product or service is higher, which in turn translates to a higher cost borne by consumers (and sometimes tax-payers in general). Besides technology and investments, externalities also arise from consumption of consumer goods, which are related to the existence of electricity - the end product of energy supply plants. From an ethical standpoint, most environmental groups and international organizations argue that many environmental problems are not quantified and thus remain as “external costs”. Such accounting systems may strengthen the status that nuclear power enjoys as a renewable energy resource. Thus, risk assessments pertaining to recycling and disposal of spent nuclear fuels, comparison of CO₂ emissions, radiological risk assessments and other economic assumptions necessary for a complete evaluation of nuclear energy risk factors needs to be developed for the implementation of sound energy policies.

82 In scientific terms, a “busbar” is an electrical conductor that serves as a common connection for two or more electrical circuits. A busbar may be in the form of a rigid bar, strands or cables and acts as a power conduit of an electrical power plant. Hence, “busbar” cost implies cost of producing electricity up to the point of the power plant busbar.

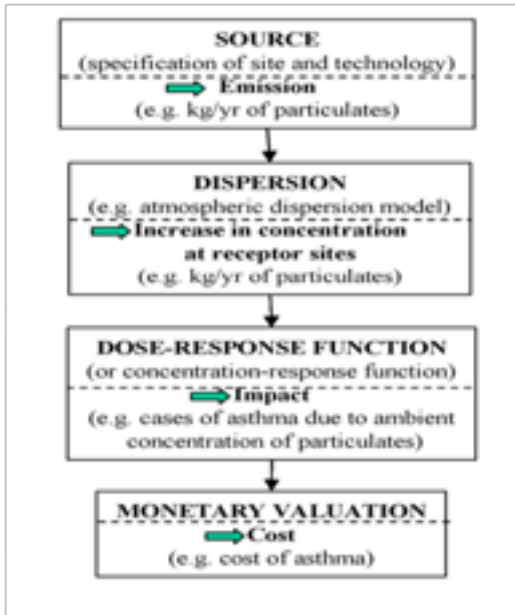


Figure 18: Impact pathway approach developed by ExternE Project⁸³

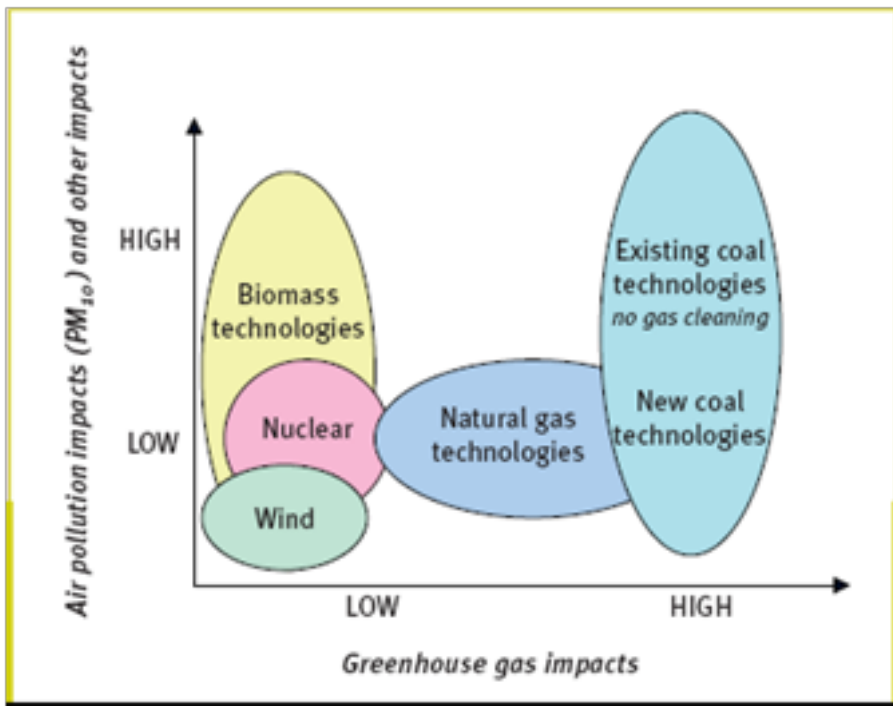


Figure 19: The results of the ExternE Project as applied to different power generating technologies

The ExternE (External costs of Energy) European Research Network (The ExternE) has been involved in compiling and estimating the factors that impact economic considerations of fossil fuel technology and renewable resources besides energy-related

83 ExternE. Externalities of Energy. A research project of the European Commission. Methodology 2005 update.

activities such as fuel cycles, and other production processes. The ExternE project⁸⁴ has developed a cost-benefit analysis wherein the costs to implement measures to reduce a specific environmental impact (burden) is compared with its benefits. An illustration of the main steps of the impact-pathway approach for the consequences of pollutant emissions is shown in Figure 18. A bottom-up approach calculates the environmental costs and benefits by following the source emissions to physical impacts.

An important tool in assessing environmental risk factors involving nuclear power (or any other energy resource) is nuclear power life cycle cost assessment. Life cycle cost assessment (LCA) is the decision support tool that is currently widely accepted for impact analysis. LCA evaluates the entire life cycle of the product from raw material extraction, acquisition and waste disposal. In the impact assessment step, environmental burdens (impacts) are identified and subjected to elaborate quantitative analysis. Regardless of their varied nature (due to different energy sources), burdens are subsequently classified independent of their type, number or size, and then reported. For the final analysis, only some of the impacts considered by arbitrary criteria to be most important are chosen and their effects calculated using an exposure-response model before being evaluated in monetary terms. In this manner, society would be not only aware of the actual cost of electricity but would also be informed that the said utility was produced from a power plant with better environmental performances.

The data in Figure 19 (ExternE: External Costs Study) illustrate that external costs of electricity generation are largely dependent on the choice of fuel, technology and location, although assumptions underlying specific technologies studied cannot be generalized. In the case of nuclear energy, the impact assessment will need to include the risk of severe radiation accidents as the major environmental burden. It is largely perceived that the weakest areas of nuclear power externality studies are the assumptions that: 1) nuclear fuel cycle wastes and other hazardous impacts are well managed. 2) The probability of nuclear accidents and its deleterious effects on society and environment, which are either ignored or neglected. Factors that might also affect nuclear externality studies are resource depletion, the extent of risk perception and capital invested in research and development.

An externality study of a 1000 MW(e) nuclear plant operation for a year in France indicated that the impact of radioactive wastes was negligible and occupational hazards were reduced owing to small mining requirements (IAEA, 2010). Less than one equivalent life lost (0.1 public and 0.02 occupational) in a 300 million European population was attributed to the yearly operation of the plant. This was calculated by incorporating the impact of severe accidents using a probability methodology since human mortality rate has a considerable effect on externalities. However, an infrequent event has only a small impact on the unit of energy generated since its impacts are

84 Over the past 20 years the multidiscipline ExternE Project series started in early 1990, is aimed at developing a consistent methodology to assess the externalities of electricity generation technologies. It uses a bottom-up impact pathway approach coupled with "EcoSense" model- an analytical software tool, for environmental impact pathway assessments. More detailed description of the ExternE methodologies can be found in the ExternE Project series (The ExternE). A decade of research has led to compilation of data on impacts from a wide range of fuels (coal and oil technologies, nuclear onshore and off shore wind, hydro and biomass) and transport externalities (road, rail, aircraft and navigation). For more details on environmental impacts see Appendix.

compared to the total amount of energy generated over a period with no accidents.⁸⁵

Table 16: External Costs study of power technologies in Belgium (mecu/kWh). Please see External Costs, <http://externe.jrc.es/infos/Belgium>, for more information.

Damages	Coal (no FGD, SCR)	Coal (with FGD, SCR)	Gas	Nuclear (3%)
Mortality (years of life lost)	87.8	15.3	2.54	0.2 + 3.3 (mill tailings)
Morbidity				0.17
Accidents	13.4	2.4	0.48	
Occupational health	n.g	n.g	N.Q	
Major accidents				0.19
Materials	0.067 + 0.37	0.067 + 0.37	0.081	0.00084 - 0.35
Crops	-	-	-	-
Noise, others	2.2	0.04	~ 0	-
Global warming (mid 3%)	1.3	0.28	0.08	-
	0.27	0.27	0.03	0.09
	17.4	18	7	
Total	122.8	36.7	10.58	4.027 - 4.4

FGD: flue gas desulphurization SCR: selective catalytic reduction

mECU = European Currency Unit. Euro now replaces ECU.

The externalities of power generating plants in Belgium are shown in Table 16.⁸⁶ The study considered both open and closed fuel cycles of nuclear plants but the differences were negligible. Three assumptions common to all countries in the ExternE project were considered for global warming: low, mid and high impact. For mid assumptions, discount rates of 1% and 3% were chosen and long-term effects due to radon from uranium mine tailings were not discounted in the case of nuclear energy. One can see that the external cost including accidents is lower for nuclear energy than that for coal.

Striking a balance between economically feasible energy technologies, which is also environmentally friendly, is a challenge faced by some countries in South-Asia. An economic feasibility study of rural South-Asia by USAID in 2006-07, indicated that while there was an immediate need for “clean” power, the true costs of existing power technologies like fossil fuel and nuclear power were not being assessed.⁸⁷ While providing cheap power to the rural areas seems to be politically motivated, the by-products of the energy source, which cause damage to health and environment, are

85 Likewise, another ExternE study of new energy power plants in six different regions in China based on different technologies can be found in “External costs of electricity generation in China”.

86 External Costs, <http://externe.jrc.es/infos/Belgium>

87 An estimate of the subsidy requirements in the USAID study indicated that Bangladesh was only 33% electrified with a subsidy loss of USD 125 million. SriLanka is 54% electrified (subsidy losses of USD 150million), Pakistan is 40% electrified(USD 126 million) and India is 56% electrified (subsidy losses of USD 7million).

not internalized in the electricity costs. Thus, the figures that show rapid growth in the power sector for Asia in recent times, actually omit certain social costs incurred at the expense of the said utility. Deterioration of buildings, respiratory problems, contamination of natural water bodies, displacement of farmers from villages and a consequent drop in agricultural produce are some of the many “unseen” problems. A pertinent question that one can ask is whether these pressing issues have been ignored by local governments in the race for economic competence while the community at large bears the brunt of such a progress. While externality assessments for various power technologies can be complicated, socio-ecological factors need to be incorporated into the accounting framework such that a variety of power technologies can be studied to provide a clean, dependable power supply for the future.

That many Asian countries aim for nuclear competence with the West is evident from the India-US civil nuclear accord of 2005. While nuclear technology is a viable option for India, this treaty essentially extends technology transfer for nuclear growth in India only for civilian use, notwithstanding the opposition from some political parties. Although nuclear technology is relatively carbon-free, nuclear accidents can be catastrophic when they occur due to which compensatory measures for civilians need to be specified. Damages to the environment caused by nuclear wastes have to be translated in terms of monetary expenses. Thus, to pave the way for a clean and safe technology transfer, the Indian government stressed the need for a civil liability protection by prospective US investors.⁸⁸ A more detailed description of the nuclear liability measures in different countries can be found in the Appendix.

A detailed nuclear impact assessment (both environmental and societal) of NPPs that include risk analysis of nuclear radiations, safety procedures employed at every stage of the nuclear power plant to its eminent final decommissioning is now a pre-requisite for all potential licensees and existing nuclear facilities in the UK. The Nuclear Installations Act (NIA, 1965) that is enforced through the Health and Safety Executive (HSE, 1974) stipulates that a site cannot have a nuclear facility unless the HSE grants a license after all necessary, precautionary measures have been taken to deal with possible risks at the nuclear facility. Under the framework of the Technical Assessment Guide (TAG), the HSE’s risk management philosophy directs Licensees or employers to comply in numerous ways such as adopt measures to safeguard workers against ionizing radiation, on-site accidents, implement safety standards at every stage of a plant’s life and provide guidance on safety assessment principles for plant workers as well as to the public. The employer is expected to make sure that these considerations are met “so far as is reasonably practical” (ALARP).⁸⁹ The Tolerability of Risks from Nuclear Stations (TOR, 1992) defines risks which are so high that they are unacceptable unless there are special circumstances and risks, which are so low that they are considered broadly acceptable. Between these two boundaries, Regulators and Licensees have to make sure that the risks have been reduced to ALARP. More

88 Due to previous experiences with Union Carbide, a “Civil Liability for Nuclear Damage” bill (2010) holds the supplier and the operator liable to any nuclear accidents as a result of sub-standard services, patent or latent defects in equipment and material.

89 ALARP is the term coined under UK law and is different from ALARA. While ALARP suggests a balance between risk and benefit, ALARA takes into account socio-economic factors.

information on the HSE-ALARP guidelines for safety standards in nuclear facilities can be found in the HSE manual.⁹⁰

A detailed impact analysis of the Pebble-bed modular reactor-Demonstration Power Plant (PBMR-DPP)⁹¹ nuclear facility in South Africa covering environmental and newly identified risk factors have been carried out through specialist studies. These studies can potentially be universally applied to any power plant site since externalities are an inherent part of power technology. The impacts were classified as effects on biophysical environment and effects on socio-economic environment. Moreover, depending on the stage of development of the power plant in which these impacts were likely to occur, impacts were further classified as i) Construction phase, ii) Commissioning phase, iii) Operational phase and, iv) Decommissioning phase. The studies also considered the impact analysis both before and after mitigation procedures were suggested. The potential construction phase impacts for a nuclear power site are as described in Table 17 (Environmental Impact Report, Sept. 2008).

From Table 17 we can see that the parameters for measuring the effects of the various biophysical impacts change with and without mitigation procedures. For some impacts, mitigation procedures have no effect on certain impacts, either due to their low probability of occurrence or due to significantly low impact coupled with short-term effect on the surrounding area. On the other hand, mitigation procedures are effective in lowering the intensity of the said impact to a low significance thereby alleviating some of the effects on the environment. More detailed information on the potential impacts during the commissioning, operational and the decommissioning phases can be found in the Impact Analysis data of PBMR's (ESKOM Holdings Limited).

While mitigation procedures will alleviate many of the environmental problems arising due to the construction of a nuclear facility, the ethical question that can be raised is whether "harm" caused to the environment by humans by overlooking seemingly low intensity environmental impacts is morally acceptable. In this context, an anthropocentric viewpoint, would tolerate such minor aberrations thereby upholding the betterment of mankind, while certain species of flora and fauna and other water bodies equally important to the local ecosystem are actually driven to extinction.

Tourism to Japan dropped significantly after Fukushima accident due to fears of safety by tourists. There are a few tourists who visit Chernobyl to see the sealed area, at a cost of USD150 a day trip.⁹²

90 <http://www.hse.gov.uk/index.htm>

91 A PBMR is a new generation high temperature helium gas-cooled reactor designed to produce 1100MW of power. Its inherent safety features and robust design make it a popular choice in countries like South Africa. At least 30,000 homes can be powered by one PBMR and a more than one PBMR's can be located in one facility to form an energy park. These relatively small power stations would be versatile and can be built anywhere provided there is a steady source of water. Their load can be adjusted depending on the need (base-load stations) or the communities they serve.

92 <http://www.theaustralian.com.au/travel/world/chernobyl-to-become-tourism-hotspot/story-fn302659-1225971300611>

Table 17: Examples of potential bio-physical and socio-economic impacts during Construction Phase of a nuclear power plant (Adapted from Environmental Impact Report, Sept. 2008).

Construction phase Impacts	Description of effects and ethical issues
<i>Bio-physical Impacts - examples</i>	
Wetlands Loss of <i>Ficinia nodosa</i> wetlands Significance: Mitigation not possible	All wetland patches within the laydown area (laydown area 1 - second section) would be completely destroyed by its use as a laydown area.
Surface water Erosion of surface soil and contamination of surface run-off. Significance: Mitigation possible	Surface soils are non-cohesive and erosion related to rain events would be a concern. It is likely that such erosion may not produce significant scars in surface soils, but the normal functioning of storm water management infrastructure could be severely impeded by siltation resulting from surface soil erosion.
Ground water Flooding of the excavated areas by groundwater. Significance: Mitigation results in low intensity of the impact. Lowering of the water table due to watering and pumping of groundwater for construction use. Significance: Mitigation results in low intensity of the impact. Drying up of wetlands due to dewatering and pumping of groundwater for construction use Significance: Mitigation results in a low intensity of the impact	Flooding will occur immediately when excavations commence due to the fact that natural ground water level is approximately 4mgb1 Lowering the water table will potentially result in saline intrusion and drying up of coastal springs. The survival of wetland ecosystems may be threatened due to dewatering activities.
Fauna PBMR DPP - habitat destruction PBMR DPP - Dust pollution off site Significance: with and without mitigation are low	Natural habitats on construction site will be permanently destroyed. Intensity low because habitats already degraded. Dust generated by construction activity will drift into neighbouring habitats and degrade them. Intensity medium because impacts are partial and temporary.
Marine flora and fauna Release of saline groundwater during dewatering of the proposed site. Organic and Bacterial contamination resulting from discharge of contaminated groundwater Significance: low intensity with and without mitigation.	Ground water will be pumped from the site for 2 years and released into the sea via existing outfall pipe. Due to the high salinity of the released water and the dynamic nature of the coastline, the intensity will be low and local in extent. As groundwater discharges from the site of the proposed development into the sea, organic and bacterial contamination of groundwater due to leaks and spillages from on-site sanitation facilities may ultimately result in contamination of the marine environment. Due to the exposed nature of the coastline, contamination is likely to dissipate quickly and is unlikely to have a significant effect on marine organisms
Air quality PM10 Significance: Intensity with and without mitigation is low	The significance rating for possible impacts to air quality by the proposed PBMR DPP.

Table 17 continued: Examples of potential bio-physical and socio-economic impacts during Construction Phase of a nuclear power plant (Adapted from Environmental Impact Report, Sept. 2008).

Social Environment	Description of Effects
<p>Introduction of people dissimilar in demographic profile</p> <p>Impact commensurate with in flow of temporary workers.</p> <p>Local /Metropolitan Government Impact</p> <p>Impact on daily movement patterns</p> <p>Public Health and safety</p>	<p>Introduction of people dissimilar in demographic profile.</p> <p>Significance: low intensity with and without mitigation.</p> <p>Potential negative increase in antisocial behaviour due to influx of workers and jobseekers into the area.</p> <p>Significance: mitigation reduces the intensity from high to low.</p> <p>Additional pressure on service delivery.</p> <p>Significance: mitigation has no effect on intensity (low to medium)</p> <p>Increased vehicle movement will contribute to existing serious traffic congestion problems and routine daily movement patterns.</p> <p>Significance: mitigation lowers the intensity from medium to low-medium</p> <p>Potential negative nuclear-related health impacts and other safety risks related to construction projects.</p> <p>Significance: low intensity with or without mitigation</p>
<p>Economic Environment:</p> <p>Employment Creation</p> <p>Employment Equity and Inequity</p> <p>Property Values and Tourism</p>	<p>Limited employment opportunities created for local communities.</p> <p>Specific disadvantaged individuals and groups are prevented from equal opportunities (Those with skills that are not in keeping with the requirements of construction firms and the project proponent).</p> <p>Impacts that the development may have on property values for homeowners in the immediate area.</p> <p>Reduction in tourism activities and visitors</p> <p>Significance: low</p>

Table 18: Examples of potential biophysical impacts of nuclear reactors in the Operation phase (Adapted from Environmental Impact Report, Sept. 2008).

Potential Biophysical Impacts	Description	Concern
<p><i>Oceanography:</i></p> <p>Humidity</p> <p>Flooding due to tsunamis**</p> <p>Exposure of cooling water intake pipes under tsunami conditions</p>	<p>Although the region has a moderate climate, the main meteorological concern is wind speed.</p> <p>Low significance.**</p> <p>Maximum credible tsunami for the site is predicted to be 4m above still water. Low probability; will not flood the PBMR-DPP if it is built 8m above MSL*.</p>	<p>Close proximity of the ocean drives a large percentage of the wind onshore thus depositing salt particles on the structure. This can have a major corrosive effect on the infrastructure.</p> <p>Not much is known about tsunamis in the coast. Undertake studies to ascertain the reasonable expected maximum tsunami effect.</p> <p>Reactor to be situated above the expected tsunami level during its lifetime.</p> <p>Spent fuel to be stored such that it is not swept away by receding waters.</p>
<p><i>Seismic Environment:</i></p> <p>Short period tectonic changes in the existing geology either from rock fall or rock movement within a radius of 230 km.</p> <p>Movements along any of the known faults or a new fault within a radius of 320 km.</p>	<p>Movement along unknown faults sometimes causes small earthquakes, but larger rock falls and movement of large volumes of sediment in the ocean may result in after shocks being transmitted.</p> <p>Pushing of the mid Atlantic Range against the African Plate can cause stress build-up of the African Plate leading to possible rock faults. Travelling seismic waves can also cause severe ground movement. These are impossible to predict.</p>	<p>High significance but probability of occurrence is negligible.</p> <p>Foundations of the facility need to be sunk into the bedrock. Completed project will have to withstand tectonic/seismic changes.</p>

*MSL: mean sea level

** Please refer to section 4.8 for an economic analysis of Fukushima accident which involved earthquake and tsunami damage, and to chapter 3. There has been a significant change in this risk factor in NPPs constructed close to earthquake faultlines.

Ecosystem functioning depends on the interaction (physical and chemical) of different species (including humans) with their environment due to which costs of preserving ecosystems and the environment has to be borne by the very people who generate them. Based on the Principles of the Convention on Biological Diversity (CBD), conservation of ecosystems should be one of the main targets of the mitigation procedures adopted during the construction phase of a nuclear site. The interdependence of biosphere on human lives stresses the need to better understand the functioning of ecosystems. Hence, in the context of preserving the biodiversity, a critical step would be to consider and share all relevant information with the stakeholders in order to arrive at effective

management strategies.

4.6. Nuclear Waste and Decommissioning

The final stage of a reactor's life cycle is characterized by nuclear waste and dismantling of the plant. Nuclear waste management has been an on-going cause for concern by countries with an active nuclear program and more recently become a global issue due to increasing environmental pollution. A nuclear reactor cycle is associated with several stages - starting from fuel mining to final waste disposal as described already in chapter 2 of this document. The life cycle of the fuel depends on reactor design and type as well as whether or not spent-fuel is reprocessed. The nature of nuclear wastes produced during various stages of the fuel cycle and their impact on society and environment have been discussed in section 2.4; as are ethical issues concerning nuclear energy technology in sections 2.3 – 2.6.

The decommissioning or dismantling of a power plant at the end of its life cycle remains an important ethical dilemma in terms of both cost and public safety. Three dismantling options proposed by the IAEA and adopted by some countries, are as follows:

- Immediate dismantling or early site release, which allows for a nuclear facility to be removed from any regulatory control within a few months of cessation of plant activities. Subsequently, the plant-site becomes available for re-use.
- Safety Enclosure option postpones the removal of reactor controls for a longer period of 40 – 60 years. The nuclear facility is placed in a safe storage configuration until further dismantling.
- Entombment involves placing the plant within a concrete structure or 'sarcophagus' so as to contain all radioactivities within itself.

Nuclear waste disposal and progressive plant dismantling are associated with a number of significant negative externalities arising due to radiation damage to life and property. The management of high-level nuclear waste, which is mostly, spent liquid waste, after the recovery of uranium and plutonium poses a considerable challenge. For example, the volume of high-level waste from reprocessing 30 tonnes of spent fuel released annually from a 1000MW(e) plant, containing more than 99% radioactivity, is about 10 cubic metres. This compares with 400,000 tonnes of ash produced from a coal-fired plant of the same operating capacity. It is estimated that the back-end of the fuel cycle (waste disposal and dismantling) contributes to an additional 10% to the overall costs per kWh (WNA, 2010). Regardless of the fact that the nuclear industry enjoys subsidies for operation, in most countries power operators are responsible for decommissioning costs, which are internalized and passed onto the consumers in the net cost.

There are ethical issues regarding this approach by the nuclear industry, owing to its reluctance to adopt a "level playing field", despite improved cost estimates established in 1986 that now allow for a better understanding of the monetary implications of dismantling a nuclear plant. Long-term disposal of high-level nuclear waste poses a serious dilemma in countries with an active nuclear program, which is further exacerbated by the growing stockpile of both spent and new nuclear weapons.

Hence, countries that wish to pursue nuclear programs for peaceful purposes need to consider the looming problem of nuclear waste disposal before embarking on costly power programs. Lawmakers need to examine the ethical implications of waste disposal policies on both human life and the environment as an overriding factor in all their decisions. As waste disposal and dismantling increase, decommissioning costs can no longer be embedded as part of construction costs but need to be evaluated separately. The total cost of decommissioning is dependent mostly on the sequence and timing of the various dismantling stages. While deferment of a stage tends to reduce its cost due to radioactive decay, it is hugely offset by the costs involved in the storage and surveillance of the said radioactive waste. Existing laws and financing nuclear plant dismantling have to incorporate “polluter pays principle”⁹³ with the aim of preserving the safety of present and future society members as well as to prevent environmental burdens of nuclear wastes.⁹⁴ Many other international organizations have issued directives regarding ethical issues with respect to dismantling of a nuclear facility, however, the underlying concerns of costs and externality assessment have not been addressed.⁹⁵

Vitrification of liquid wastes and underground geological repositories are two of the proposed choices for the maintenance of high-level waste, which still await political consent in some countries. Deep multiple barrier geological repositories at depths ranging from 250m to 1000 m are said to ensure that there is no radiation leakage into the biosphere. Thus, countries like Finland and Sweden have already approved sites for geological burial while the Waste Isolation Pilot Plant in New Mexico is the only geological repository in the US, operational since 1999. The proposed site at Yucca Mountain is still awaiting approval from the NRC and environmental protection Agency (EPA) after some decades due to concerns regarding its suitability. Although many nations favour the idea of deep disposal, the apparent delay in pursuing such a program stems from the lack of communication between decision makers and regulators, lack of advocacy regarding nuclear waste disposal coupled with the failure to educate people on the effect of such programs on human life and biodiversity. Hence, while public reluctance to co-operate with authorities in decision-making is also fueled to a large extent by incidents of nuclear accidents and their after-effects, it does little to boost public confidence in law makers.²³

There are also different views among nations as to whether buried nuclear wastes should be made retrievable from repositories. From an ethical standpoint, while future

93 Article 16 of the 1992 Rio Declaration on Environment and Development.

94 Refer to a discussion of the Polluter Pays Principle in ECCAP WG7 report.

95 Nearly a quarter of a century after the Chernobyl meltdown, large numbers of wild boars are fairly radioactive. The Environment Ministry has paid out 555,000 USD as compensation to hunters for wild boar meat that was contaminated by radiation and hence unfit for consumption. The amount paid off has nearly quadrupled since 2007 due to the rising levels of radioactivity. The animals showed an average of 7000 becquerel per kilogram of radioactive cesium (¹³⁷Cs); well above the specified limit of 600 becquerel. There is considerable cause for alarm since wild pigs with considerably high levels of contamination are frequently killed by hunters in the forests bordering Germany and The Czech republic. Bavarian hunters have been feeding the pigs with Giese salt, which when ingested is known to accelerate the excretion of the radioactive substance. A pilot program that was started about a year ago to reduce contamination levels in these animals, has brought down the numbers have significantly. However, according to the Environment Ministry, the problem is expected to last for another 50 years at least. Further discussion of Fukushima is in section 4.8 and chapter 3.

generations might consider this as a valuable resource, a permanent disposal leads to security concerns. Societal implications and community engagement are of utmost importance for planning and implementation of large-scale nuclear waste disposal.

4.7. Economic Analysis of Chernobyl and Fukushima

The cost and period of decommission in Three Mile Island was about USD 1 billion (NRC, 2009).⁹⁶

In the case of Chernobyl, construction of a new shelter is needed. Since the Ukraine government said it cannot pay total cost for the new shelter the European Bank for Reconstruction and Development (EBRD) was established in 1997 to manage a Chernobyl Shelter Fund for global collection of money.⁹⁷ EBRD (2011) published, "As of end-2010, the total amount received for the Chernobyl Shelter Fund is €990 million including the proceeds of management of liquid assets, the EBRD contribution and some projected income". Meanwhile, WNA (2011) estimated the total cost of the new shelter at €1.2 billion (USD 1.64 billion). Ukraine continues supplying nuclear electricity to other countries losing foreign currency and overcoming the financial deterioration by the decommissioning.

Chernobyl affected several countries, and Belarus alone estimated the losses over 30 years at USD 235 billion (Chernobyl Forum, 2006). Ukraine continues supplying nuclear electricity to other countries forgetting foreign currency and overcoming the financial deterioration by the decommissioning. The Chernobyl Forum is a joint initiative of the IAEA, WHO, UNDP, FAO, UNEP, UN-OCHA, UNSCEAR, the World Bank and the governments of Belarus, the Russian Federation and Ukraine, and the costs of the accident were shared across not only those three countries, but across much of Europe as well.

The Fukushima accident has revealed the high cost that will be required to clean up the contaminated land as well as for making the site safe over a number of years/decades. TEPCO said it will pay JPY 53.1 billion (USD 682 million) for decommissioning 250,000 tons of polluted water (about JPY210,000 per ton) to AREVA.⁹⁸ It has been claimed that a Japanese company would charge only JPY100,000 per ton for decontamination and to treat radioactive waste water materials from 98% of the polluted water.⁹⁹ However, the contract of the main waste water system was issued to overseas companies, AREVA in France and Kurion in US.¹⁰⁰ Overall it is estimated by the Japanese government and USA that there may be 400 thousand cubic metres of soil to clean (taking top soil 5cm deep over 800 km²; and the sludge in the sea around 20km radius from Fukushima Daichi, totally 1.2 million tons of soil. Just for evacuated schools there is 38 thousand

96 *The New York Times*. 1993. 14-Year Cleanup at Three Mile Island Concludes. 15 August 1993.

97 See <http://www.ebrd.com/downloads/research/factsheets/chernobyl25.pdf>

98 Yomiuri Newspaper, 27 May 2011, See <http://www.yomiuri.co.jp/science/news/20110527-OYT1T00959.htm>

99 Estimate by Dr. Aritomi Masanori.

100 According to the question of Hon. Murakami Seiichiro, a lower house member of the Diet, in an administration control committee meeting.

cubic metres of soil to deal with, with 3 thousand tons of contaminated waste from school yards. If the 30km radius zone of farmland is included it will be over 6 million tons.¹⁰¹ There are already significant traces of radioactive cesium and other waste in incineration plants in Tokyo, which are releasing these contaminants back into the atmosphere.

The costs for cleaning up the contaminated land, losses to farming and fishery, losses to land and property, and medical liability bills are not yet possible to be calculated. However, AERA estimated it would be JPY 100 trillion (USD 1.3 trillion) to clean up the radioactive pollution around Fukushima Daiichi NPP. However, AERA released data that a lot of incinerators for refuse burning of waste in all areas of Japan begin burning nuclear waste.¹⁰² The Japanese Ministry of Finance national budget for 2011 is less than the clean-up cost, at JPY 92 trillion.¹⁰³

TEPCO will not be able to pay cost for the decommissioning of Fukushima Daichi NPP. This means that Japanese people including future generations will continue paying a lot of money to western conglomerates for decommissioning as well as continued developmental costs. There are two main proposals, with the estimation of Toshiba and Westinghouse taking ten and a half years, whereas the estimate from Hitachi and general Electric is 30 years.

Another interesting case in Japan is the costs of maintaining non-operational nuclear reactors. As of September 2011 the Japan Atomic Energy Authority notified that only 11 of 54 reactors in the country were producing electricity, because many were shut for maintenance (compulsory every 13 months), and some local authorities are now delaying their reopening.¹⁰⁴

The expensive costs by big nuclear disasters can therefore become a big profit over the long period that decontamination is required for companies such as AREVA. The cost of negative externality is paid by the public since the company, TEPCO, is almost unable to pay, not only by those in this generation but also by future generations. The estimated cost to build Fukushima Daiichi accident is JPY 502 billion (USD 7 billion).¹⁰⁵

The scale of the burdens includes both direct damage caused by the accident and indirect costs incurred including actions to seal off the reactors and mitigate the consequences in the exclusion zone. Resettlement of people and construction of new housing and infrastructure to accommodate them. The major income of the contaminated areas around both Chernobyl and Fukushima was agriculture (and fisheries in the Fukushima case). Social protection and health care for the affected populations is needed. About 7 million people are now receiving (or are at least entitled to receive) special allowances, pensions, and health care privileges as a result of being categorized as in some way affected by Chernobyl (Chernobyl Forum, 2006).

101 See http://www.aera-net.jp/summary/110529_002412.html

102 AERA-net.jp, See http://www.aera-net.jp/summary/110529_002412.html,

103 Ministry of Finance. 2010. Highlights of the Budget for FY2011. Tokyo. See <http://www.mof.go.jp/english/budget/budget/fy2011/e20101224a.pdf>

104 See <http://www.jaea.go.jp/04/turuga/anncer/page/kaitou/kaitou2-1.html>

105 Source: Fukushima prefecture (2010), “原子力発電所の設置概要表~平成20年7月”, <http://www.pref.fukushima.jp/nuclear/hatsudensyo/gaiyou.html>

Research is needed on environment, health and production of clean food, with monitoring of the environment and methods for decontamination and disposal of waste. Further research on nuclear energy technology is needed, to allow people to live without continuing mental anguish about their health. In the Japanese case, many consumers are now purchasing Geiger counters, to try to monitor their own safety. We could expect further devices and assays to be produced for consumers and farmers so that people can exercise their autonomy to make choices about the risks they will accept. They can also minimize the chance of harms by dietary, occupational and other choices (Obata, 2011).

The closure of agricultural areas and industrial facilities is costly, and in Japan there is an acute shortage of farm land (Uejima, 2011). There are also costs to other species (Bosworth, et al., 2011). The public movements against nuclear energy also lead to development costs for generation of new sources of electricity, including alternative power plants, and higher costs of fossil fuel imports.

4.8 New Generation Nuclear Reactor Technology- Generation IV Nuclear Reactors

The nuclear era that started in the early 1950s, has spawned three generations of nuclear reactors: early prototype reactors, commercial power reactors and advanced light water reactors. The present population of nuclear reactors being used worldwide is designated as generation II and III reactors, and currently supplies 14% of the global energy demand. However, in the coming years it is anticipated that an increase in the world's population from 7 billion to 10 billion would lead to a rise in the global energy demands making it imperative to adopt alternate, clean sources of energy like nuclear and hydro-power. It is also expected that nations that have not been using nuclear power might eventually do so in the interest of minimizing GHG emissions. At present 40 Generation IV reactors are in operation worldwide and 60 more being constructed to satisfy the needs for clean energy and a consequent reduction in carbon emissions.

While nuclear energy is utilized by many countries as the first choice of power, the underlying challenges faced by the nuclear industry in the form of nuclear plant accidents, high costs of construction and the need for proper waste disposal pathways from uranium mining to spent nuclear fuel cannot be ignored. The use of nuclear material for subversive activities is presently an ongoing cause of debate by the international community as they strive to advocate nuclear non-proliferation via the peaceful use of nuclear power. The fact that nuclear power is a major negative externality and the long-term effects of radiation damage on all life forms and the environment is also a major cause for concern. Nevertheless, both developed and developing countries remain unfazed in the light of all these impediments and are going ahead with renewed vigour to adopt nuclear technology as one of the preferred choices to meet the energy needs of their country. Developing nations have incorporated nuclear technology as one their choices among a portfolio of other green renewable resources like wind, biomass and hydro power either through foreign collaborations or through indigenous, government funded technologies.

While there are many drawbacks to harnessing nuclear energy, nuclear technology

has also made advances in recent years. Countries like the USA and Japan have invested heavily into basic research for developing new and robust reactor designs using alternate fuels and modified reaction pathways (WNA Feb 2010, WNA June 2010, US DOE). While generation II reactors are still safe and reliable to use, new reactors with improved cost effective designs and fuel efficiency now supersede them. These are the generation III and III-plus reactors that are now either under construction in Japan or ready to be ordered. Generation IV nuclear reactors are still being designed and are expected to be available by 2030. Most of these ventures are largely through international collaborations. Some of the improved features of third and fourth generation reactors are as follows:

- Simpler, more rugged design making it easier to operate and less prone to operational errors.
- Higher availability and longer operating life of about 60 years.
- Standardized design for each type of reactor makes it easier to obtain licensing, reduce construction time (2-3 years) as well as capital costs.
- Reduced possibility of core melt accidents, resistance to radiological release due to aircraft impacts.
- Higher burn-up to reduce fuel use and hence the amount of waste.
- Burnable absorbers ("poisons") to extend fuel life.
- Incorporates passive safety features that do not require active controls in the event of a malfunction.

Westinghouse AP600 is a generation III reactor that obtained certification in the USA in 1999. It is a 600Mwe reactor and has passive safety features. The AP1000 scaled up from AP600 is the first generation IIIplus design to receive final certification. The System 80+ is an advanced APR and with improved design features is expected to be marketed in South Korea as APR 1400 by 2013. Likewise, the IAEA's international project on Innovative Fuel Reactors and Fuel Cycles (INPRO) is focused mainly on the needs of developing countries through a joint collaboration with USA and Russia. GE Hitachi Nuclear Energy's ESWBR is another Generation IIIplus technology product that will produce 1520 Mwe of power and has a life of 60 years. Small-scale reactors with capacities of 600 – 1700 Mwe have been designed by Hitachi-GE that will further reduce costs. More detailed information on Generation III and IIIplus nuclear reactors developed through international collaborations can be obtained from World Nuclear Agency report (WNA, 2010a).

The generation IV international forum (GIF) was set-up in the year 2000 and represents 10 countries including the USA, France, Brazil, Argentina, UK, Russia among others (WNA June 2010) that are committed to developing advanced reactor technologies for the future.¹⁰⁶ In 2002, six reactor technologies were selected on the basis of being cost-effective, providing a safe and sustainable source of energy and resistant to

¹⁰⁶ India is not part of the GIF but is developing a FBR (KAMINI) that will exploit the country's rich thorium reserves. Its ambitious three stage nuclear program involves utilising PHWR's (CANDU) followed by 500 Mwe FBR's to breed U-233 from thorium. In the final stage, advanced nuclear power systems will process U-233. The FBR's are fuelled by uranium-plutonium carbide with a thorium blanket to breed fissile uranium. Spent fuel will be reprocessed to recover any fissile material for reuse. The two options for the third stage are an Advanced heavy water reactor and subcritical Accelerator-Driven Systems. The project is expected to be operational in 2011 and is designed for a life span of 100 years with 65% fuel utilisation of thorium via U-233.

proliferation. The estimated budget for this project is about USD 6 million over 15 years. Six technologies utilizing a closed fuel system were selected as the basis of constructing the most advanced, efficient and safe nuclear power reactors to combat the global challenges of energy requirements and are shown in Table 19 (WNA 2011). The reactor design of each technology is shown in Figure 25 of the Appendix (Idaho National Engineering and Environmental Laboratory, INEEL) .

Table 19: Generation IV nuclear reactor technology (WNA, 2011)

	Coolant	Temperature (°C)	Pressure	Fuel	Fuel cycle	Size (Mwe)	Uses
Gas-cooled fast reactors (GFR)	He ^a	850	high	²³⁸ U ⁺	Closed	1200	Electricity and hydrogen
Lead-cooled fast reactors (LFR)	Pb or Pb-Bi ^b	480-800	low	²³⁸ U ⁺	Closed, regional	300-1200	Electricity and hydrogen
Molten salt fast reactors (MSR)		700-800	low	UF in salt*	Closed	1000	Electricity and hydrogen
Molten salt reactor-Advanced High-temperature reactors (MSR-ATR)		750-1000	low	UO ₂ particles in prism	Open	1000-1500 30-150	Hydrogen
Sodium fast-cooled reactors (SFR)	Sodium	550	low	²³⁸ U & MOX	Closed	300-1500 1000-2000	Electricity
Supercritical water-cooled reactors (SCWR)	Water	510-625	Very high	UO ₂	Open (thermal) Closed (fast)	1000-1500	Electricity
Very high temperature gas reactors (VHTR)	Helium	900-1000	High	UO ₂ particles in prism or pebbles	Open	250-300	Hydrogen and electricity

^aHelium gas, ^bLead-Bismuth, ⁺with some ²³⁵U or ²³⁹Pu, *Uranyl fluoride

4.9. Case study of China's Nuclear Development

4.9.1. Current Situation of Nuclear Power in China

The People's Republic of China has 14 nuclear power reactors in operation, more than 25 under construction and more about to start construction soon. Currently, the country has the world's largest number of reactors being constructed for any country.

Because of the additional reactors that are planned, and the cutting-edge technology being adopted, the expansion is projected to give more than a ten-fold increase in nuclear capacity to at least 80 GWe by 2020, from 10.8 GWe in 2010. In 2020, this will account for 4% of the total national electricity generation. The figure is planned to be raised to 200 Gwe by 2030 and 400 Gwe by 2050, exceeding the current total capacity of all NPPs in the world today. At that time, China will be self-sufficient in reactor design and construction.¹⁰⁷ Figure 16 shows the distribution of NPPs in China and Table 20 indicates the detailed information of each NPP that is in operation at the moment. China is expanding its nuclear industry map from the eastern coastal area to inland as well. In 2006, China National Nuclear Corporation signed agreements with Hunan province to launch nuclear projects.

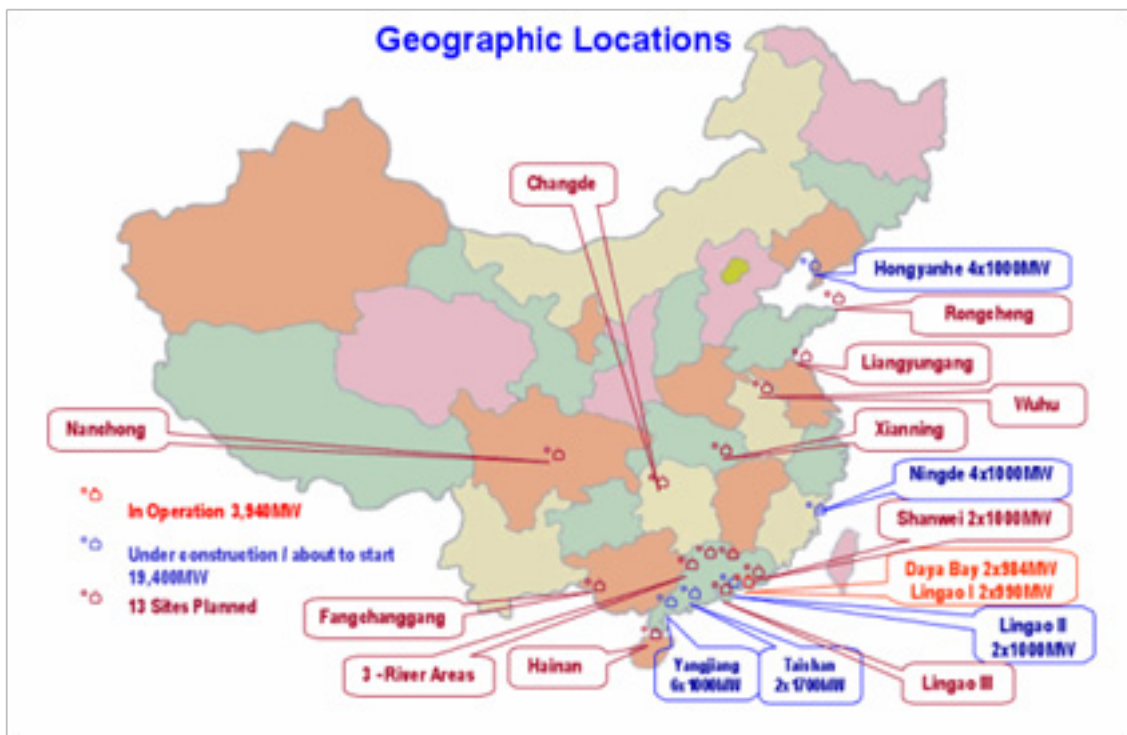


Figure 19: Nuclear Power Plants in operation and under construction in China

Table 20: The NPPs in operation in China

Units	Province	Net Capacity (each)	Type	Operator	Commercial Operation
Daya Bay 1&2	Guangdong	944 MWe	PWR	CGNPC	1994
Qinshan Phase I	Zhejiang	279 MWe	PWR (CNP-300)	CNNC	April 1994
Qinshan Phase II, 1-3	Zhejiang	610 MWe	PWR (CNP-600)	CNNC	2002, 2004, 2010
Qinshan Phase III, 1&2	Zhejiang	665 MWe	PHWR (Candu 6)	CNNC	2002, 2003
Ling Ao Phase I, 1&2	Guangdong	935 MWe	PWR	CGNPC	2002, 2003
Tianwan 1&2	Jiangsu	1000 MWe	PWR (VVER-1000)	CNNC	2007, 2007

107 World Nuclear Association. 2011. *Nuclear Power in China*, <http://www.world-nuclear.org/info/inf63.html> (Accessed 20 August, 2011)

Units	Province	Net Capacity (each)	Type	Operator	Commercial Operation
Ling Ao Phase II, 1&2	Guangdong	1037 MWe	PWR (CPR-1000)	CGNPC	Sept 2010, (Aug 2011)
Total: 14		11,271 MWe			

Sources of Figure 19 and Table 20: WNA. 2011. Nuclear Power in China. URL: <http://www.world-nuclear.org/info/inf63.html>

Among the 14 operational reactors, three (Qinshan Phase I and Qinshan Phase II, 1-2) were indigenously designed, four (Daya Bay 1&2, Ling Ao Phase I, 1&2) were purchased from Framatome, France, two (Ling Ao Phase II, 1&2) from Alstom, France, and two (Qinshan Phase III, 1&2) from Atomic Energy of Canada (AECL). For Tianwan 1&2, the construction was carried out by a largest cooperation project ever between China and Russia, while China contributes USD1.8 billion to cover nearly the half of the total USD3.2 billion cost. For Qinshan Phase II 1-3, the first two reactors were locally designed and the third one has 77% local content.

China is now working on its generation IV nuclear reactor technology, which can efficiently reduce the consumption of uranium and minimize the production of radioactivity wastes. The country has already brought its first generation IV nuclear reactor online, becoming the 8th country in the world that successfully tested a fast-breeder reactor and use it to produce power, following the United States, Russia, France, the U.K., Germany, Japan and India. According to the Chinese Institute of Atomic Energy (CIAE), this was a result of more than 20 years of research. The brand new reactor has an electric output of 20 GWe and has been connected to the country's main grid in August 2011. In late August 2011, China's first million kilowatt level NPP outside reactor nuclear instrument system design proposal passed its evaluation, which means China is going to launch products the result of its indigenous R&D for outside reactor nuclear instrument systems to succeed the ones currently implemented in China which are all imported.

4.9.2. Uranium Importation

Uranium production is concentrated in limited countries such as Canada, Australia, Russia, Kazakhstan, Namibia, to name just a few. The known uranium reserves would only last for about 60 years if there is no upgrade of current technology for more efficient use of the energy resources. As for China, according to IAEA, its uranium reserves rank below the top 10 in the world (Yang and Huang, 2009). Around 200 small-to-medium-sized uranium deposits have already been discovered in China, most of which are located in the south eastern part of the country.

Due to the expanding uranium gap, China has adjusted its uranium strategy both by shifting the uranium exploration to northern China and by increasing the uranium imports from foreigner countries. The country has established firm cooperation links with those uranium suppliers all over the world especially in Africa, where around 18% of the known recoverable uranium resources are located. For example, Niger has

approved two exploration licenses to the China Nuclear Uranium Corporation (CNUC) and ZXJOY Invest. The total amount of uranium imports of China in 2010 was 17,136 tons, with raw materials shipped from Kazakhstan, Uzbekistan, Namibia, Russia and Australia.¹⁰⁸

The huge quantity of uranium imported by China also has an inevitable impact on the global market. The spot price of uranium is actually decided by the private contracts, and after the peaking at USD136 a pound in June, 2007, the market did not perform well until March 2011, then the spot price moved from USD40 a pound to USD62. It is estimated that in the next two years, it will settle in that USD70-75 range, mainly caused by the Chinese huge energy needs.¹⁰⁹

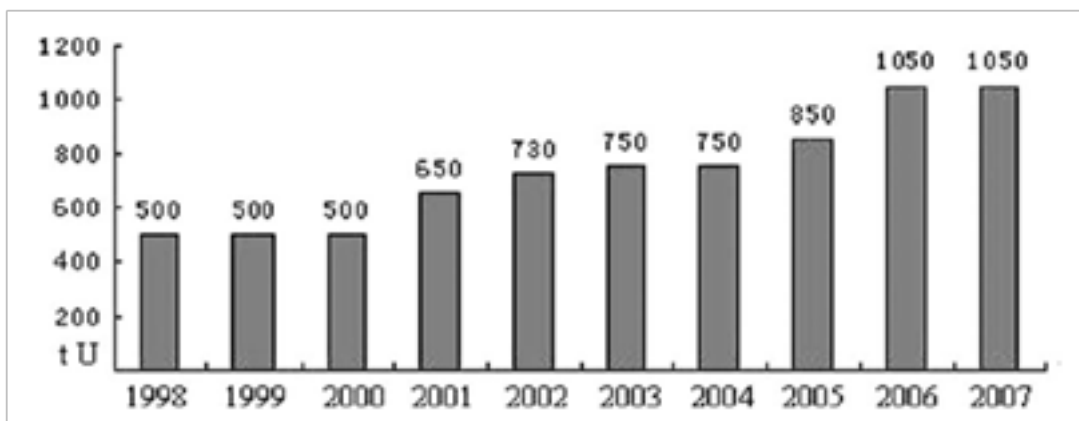


Figure 20: China's estimated uranium production from 1998 to 2007

Source Yang G. and Huang W. 2009. The status quo of China's nuclear power and the uranium gap solution, Energy Policy

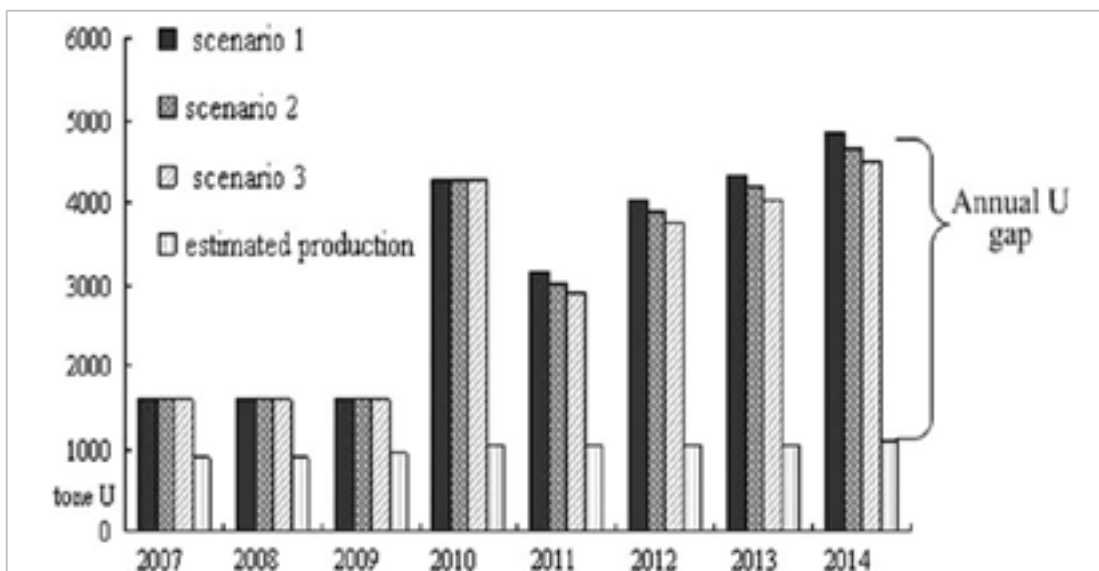


Figure 21: Uranium annual gap to 2014 in China

108 The Global and Mail. 2011. *Chinese Energy Needs Send Uranium Market Soaring*, See.

<http://www.theglobeandmail.com/globe-investor/chinese-energy-needs-send-uranium-market-soaring/article1872125>

109 Wall Street Journal. 2011. *China Increases Uranium Imports*. See <http://online.wsj.com/article/SB10001422052748704754304576095361398263834.html> (Accessed 20 August, 2011)

Source Yang G. and Huang W. 2009. The status quo of China's nuclear power and the uranium gap solution, Energy Policy

But one thing that needs to be considered is the uranium imports in China slowed during the first half of 2011 because of the industry uncertainty caused by Japan's Fukushima nuclear crisis. According to news report, the figure released by General Administration of Customs showed that the total import of uranium in the first six months in China was 5,356 tonnes, a 13 percent year-on-year drop.¹¹⁰ The uranium price kept going down since the beginning of 2011, dropping to USD52.79 a pound in July 2011.

4.9.3 Nuclear Policy

Current Framework

At present, the Chinese government sets the blueprint and the overall plan is implemented by various agencies. China Atomic Energy Authority (CAEA) is the national authority for nuclear technology, in charge of the administration and organizing argumentation on major nuclear R&D projects as well as promotion the peaceful use of nuclear energy by complying to the regulations of IAEA.. Meanwhile, the State Development and Planning Commission is also in charge of approving new nuclear projects nationwide. All the operational NPPs in China belong to China National Nuclear Corporation (CNNC) and China Guangdong Nuclear Power Group Holding Co. Ltd (CGNPC), respectively. The former is a state-owned enterprise under the direct management of the central government. It is no doubt the core of the national nuclear technology industry. The company is mainly engaged in scientific research and construction work. The latter, established in 1994, is a large corporation under the leadership of the State-owned Assets supervision and Administration Commission (SASAC) It owns twenty wholly-owned or controlling subsidiaries for carrying out operation projects and developing self-reliant research as well. For safe operation of NPP, China's National Nuclear Safety Administration (NNSA) independently supervises all the domestic nuclear power facilities under CEAE and it is responsible for regulations, construction operating licenses and monitoring plant operations. As suggested in January 2011, by the State Council Research Office, the NNSA is going to be an entity directly under the State Council and an independent regulatory body with authority. Founded in 1984, CNNSA itself is a quite complicated organization, as Figure 22 indicates its structure nationwide.

110 Asia News Network 2011. *China's Uranium Imports in Marked Decline*, .
http://www.china.org.cn/business/2011-08/030content_2312496.htm

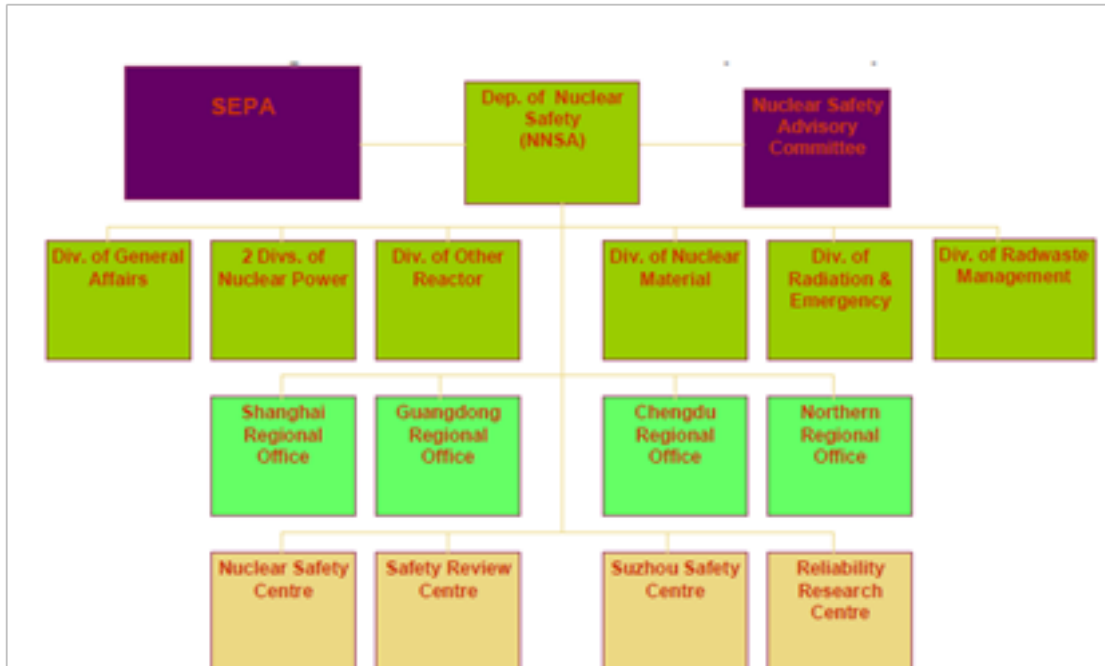


Figure 22: National Nuclear Safety Authority

Source: Kadak, A.C. *Nuclear Power: "Made in China"*.

The China Nuclear Energy Association (CNEA) is a national non-profit and non-governmental organization (NGO) established in April 2007. This organization serves as the bridge among its members, the Chinese government and overseas counterparts. Through implementing national policies, CNEA aims at further compel the reliability and safety of energy utilization. Besides the independent supervision of NNSA and the contribution of CNEA several laws and regulations have already been launched to ensure the peaceful utilization of nuclear energy, and more are under construction, for example, *The Atomic Energy Act*, *Safety Supervision and Management Regulations of Radioactive Material Transport*, to name just a few (Zhou and Zhang, 2010).

For the overall developing plan of nuclear technology, the county has set the following points as the key elements: PWRs will be the mainstream but not sole reactor type; nuclear fuel assemblies are fabricated and supplied indigenously; domestic manufacturing of plant and equipment will be maximized, with self-reliance in design and project management; international cooperation is nevertheless encouraged.¹¹¹

The Medium-to-Long Term Plan for the Nuclear Legislation in China

In 2001, the issue of *Convention on Nuclear Safety* of China's National Report detailed the policy of China's nuclear energy. In October 2007, the National Development and Reform Commission (NDRC) issued *The Medium-to-Long-Term Plan for Nuclear Power in China (2005~2020)*, which serves as a guidance for the future development of China's nuclear industry. In the fifth chapter *Security Measures and Policies*, the plan urges to accelerate the legislation process to further secure the healthy development of nuclear

111 World Nuclear Association. 2010. *India, China and NPP*, <http://www.world-nuclear.org/info/inf80.html>

industry.

The plan shows that during the eleventh five year plan, more research work will be carried out to formulate the industry standards within the existing legal framework. The plan also urges relevant department to perfect the laws and rules on nuclear security and pass the *Atomic Energy Law*.

China Atomic Energy Law Legislation

The legislative process of the Atomic Energy Law first started in 1984, and the first formal draft was submitted to the State Council. In 1995, the Eighth National People's Congress (NPC) Standing Committee declared the Atomic Energy Law as one of the first class legislative bills for deliberation. But from 1990 to 1998, the frequent reforms in national management system shelved the legislation process.

Only in 1999, the legislative process restarted with more efforts put in and the newly established Commission of Science, Technology and Industry for National Defence took the overall charge at that time. Based on extensive research and opinions collected from experts, the next draft of the Atomic Energy Law was proposed in June 2010, which marked the fourth legislative initiative. In order to follow the pace of building a sustainable society, in the end of 2010, Legal Affairs Office of the State Council held several legislative symposiums to study the feasibility and necessity of atomic energy legislation. Again, many politicians and academicians appealed to commence the fifth legislative initiative as soon as possible. With the authorization of *2011 Legislative Plan*, issued on 31 January 2011, the Ministry of Industry and Information Technology (MIIT) and the National Energy Administration (ENA) jointly led the fifth draft of the Atomic Energy Law. As the Chinese government has placed great attention on the safety operation of NPPs after Fukushima accident, the China Nuclear Energy Association (CNEA) is now working with the Ministry of Industry and Information Technology Ministry of Environmental Protection and other relevant ministries to formulate the draft.

Problems of Nuclear Policy-Making

In his report, Dr. Wang Jin, Director of the Nuclear Policy and Law Center in Peking University, figured out the difficulties and problems of existing the current policy-making mechanism in China. The biggest problem is that the management system is too complicated and lacks efficiency, with too many departments taking charge.¹¹² As different departments have their own opinion over the legislation, overall agreement is hard to be achieved, and the lack of consensus severely hinders the smooth advance of the process. China, as a member of IAEA, hasn't yet enacted effective laws to regulate nuclear safety and monitor radiation.

Domestic and foreign news media also criticizes a lot about Chinese slow pace of nuclear legislation. In an interview done by *Wang Daily*, a Taiwan news journal, Zhang Yuhui, deputy director of the R&D department of CNEA said that is was still too early to say when the draft of the Atomic Energy Act would be submitted to the Standing Committee of the National People's Congress, as four governmental agencies joint

112 Wang J. 2011. *The Current Situation and Issues of China Atomic Energy Law Legislation*, <http://china.nrdc.org/>

hands in making the law, and many overlapping areas need to be clarified and the jurisdiction of each part need to be efficiently divided.¹¹³

Moreover, the comparative study on legislative intents and their priorities of atomic energy law in different countries and areas show that, the key words in China's laws are "maintain", "control", "promote", "safeguard", while the ones in USA are "manage", "promote" and "welfare", and in Japan, are "promote", "social welfare" and "living standard".¹¹⁴ Long-term development planning is necessary to ensure the improvement of people's living standards and social welfare system would be bettered through a mature law system.

Nuclear experts and academicians also express their concerns over the status quo of the nuclear education policy in China, as at presents, China lacks the qualified people to handle the vast expansion of NPP in the foreseeable future and no priority has been given to establish an educational system to cultivate young professionals in any of the existing laws and rules. According to the Commission of Science and Technology for National Defence, there is a need for 13,000 new university graduates in the nuclear industry in the next 15 years (Lau, 2005). But among the 360,000 graduates from science and technology departments across the nation, few of them have received training in nuclear engineering disciplines (Andrew C, 2006). In order to face the widening gap, although in *The Medium-to-Long-Term Plan for Nuclear Power in China (2005~2020)*, NDRC promised to set up nuclear technology majors in various top-level universities, such as Tsing Hua University (Beijing), Jiao Tong University (Shanghai), Jiao Tong University (Xi'an), and the Guangdong Nuclear Power Company is instituting special programs with universities to provide the needed personnel for their expansion plans, the specific plan is still vague and more details need to be decided.

4.9.4. Nuclear Safety

Overview

The budget report of Ministry of Environmental Protection of the People's Republic of China showed that in 2011, the country would spend more than RMB 100 million (USD 16 million) in nuclear security supervision across the country and half of that amount would be spent specifically in upgrading the technology of radiation appraisal.

China suspended approvals for new nuclear projects following the Fukushima accident on 16 March 2011 and launched a six-month long national nuclear facility safety check in April 2011. The completion of the examining work of Fangjiashan NNP marked the end of the security check project. It's estimated that the approval procedure of

113 Wang Daily, 2011. China's nuclear safety laws progress slowly, 17 March 2011. See: <http://www.wantchinatimes.com/news-subclass-cnt.aspx?cid=1105&MainCatID=11&id=20110317000012> (Accessed 2 Sep, 2011)

114 Wang J. 2011. *The Current Situation and Issues of China Atomic Energy Law Legislation*, Powerpoint slides. See: http://china.nrdc.org/files/china_nrdc_org/10b%20-%20Wang%20Jin%2020110620%E6%B1%AA%E5%8A%B2%E5%AE%9A%E7%A8%BF%E5%8C%97%E5%A4%A7_%E6%88%91%E5%9B%BD%E5%8E%9F%E5%AD%90%E8%83%BD%E7%AB%8B%E6%B3%95%E7%9A%84%E7%8E%B0%E7%8A%B6%E4%B8%8E%E8%AF%BE%E9%A2%98ENG.pdf

construction of new NPP will restart at the beginning of 2012.

Even though China is expanding nuclear energy production, the Chinese government also guarantees to raise the proportion of other renewable clean energies, such as hydroelectric and solar energy, in the whole energy structure. Xie Zhenhua, the deputy director of National Development and Reform Commission, announced at the Australia-China Climate Change Forum in March 2011 that in the future, nuclear technology would take less than 3% in the overall energy structure for generating electricity in China.

Radiological Dangers for Workers and Local Population

According to *National Radiological Accident Casebook 1988-1998*, 332 radiological accidents have happened in mainland China, with 966 people receiving exposure. Radioactive materials were lost in 80% of the accidents and among 584 lost radioactive materials, 256 were failed to be collected back. The report to the IAEA, *Lessons from the Radiation Accidents in China over the Past 40 years (1954-1994)*, suggested that about 80% of the accidents were liability accidents related to human factors. Further, the poor training of nuclear industry workers and inhabitants within the radiation zone makes them most vulnerable group of people.¹¹⁵

In 2005, Disease Prevention and Control Center in Lianyungang, Jiangsu Province carried out a survey to the inhabitants who live within the radius of 30km away from the Tianwan NPP. Statistics showed, among 764 interviewees who have received high education, only 7% were worried about the hazardous NPP, and 40% people acknowledged that they had never thought about the potential danger of living near nuclear power plant. As for 2833 illiterate persons who were interviewed in the survey, 72% of them showed no concerns at all, while those who worried or sometimes worried about the radiation accounted 3% and 25% respectively (Yang et al., 2006).

Table 21: Recognition of the harm of NPP by people with different education levels

Education Background	Worry a lot		Worry sometimes		Never worry		Total n
	n	%	n	%	n	%	
Illiterate Person	94	3.3	701	34.7	2038	71.9	2833
Elementary School	224	5.3	1389	33.0	2598	61.7	4211
Secondary School	284	5.8	2079	42.4	2535	51.8	4898
High School	189	5.2	1701	46.8	1743	48.0	3633
Junior College	73	5.2	716	51.3	606	43.4	1395
University and Above	50	6.5	414	54.2	300	39.3	764
Total	914	5.2	7000	39.5	9820	55.4	

Source: Yang et al., 2006. Investigation and Analysis of Residents around Tianwan Nuclear Power Plants

115 Zhang, Y., Ma, J. and Yang, J. *The Lessons from the Radiation Accidents in China over the Past 40 years (1954-1994)*. China Institute for Radiation. <http://www.iaea.org/inis/collection/NCLCollectionStore/Public/29/064/29064264.pdf>

The Possibility of a Serious, Large-Scale Accident

During the past few decades, the pre-warning and emergency response monitoring system for nuclear and radiation have been constantly strengthened by the joint effort of different departments, with the launch of 21 online pre-warning monitoring sports and 4 data collection centres in 2009.

Up to 2009, the nuclear facilities in service in the country maintained a safe operation and according to the 2009 *Nuclear Safety Annual Report* issued by National Nuclear Safety Administration (NNSA), there were no safety related events or accidents of level 2 or above in any operational NPPs, research reactors, unclear fuel cycle facilities, radioactive waste storage, treatment and disposal facilities or radioactive material transportation activities. Although some minor events and non-conformance items of nuclear facilities in operation occurred, they were all handled in a timely manner.

However, a small scale explosion happened in Tianwan NPP in August 2008. According to *Mingpao*, the news journal in Hong Kong, a fire was caused by the explosion and a fireman was injured. No official reports were released to the public and the officials claimed that the reactor was sealed automatically with no abnormal situation occurring to other facilities. Thus, the possibility of radioactive leak was said to be zero.¹¹⁶

In May 2010a nuclear leak accident happened in Daya Bay NPP, Shenzhen. Daya Bay NPP is the first large-scale commercial NPP in China and it is located only 54km away from Hong Kong. The news was immediately blocked by China Light & Power Group, who is a 25% equity partner of the NPP, in order not to arouse panic among local people. Two weeks later, the company affirmed that there was a light nuclear leak in the NPP, and it wouldn't threaten daily life and it was unnecessary to rate the nuclear danger by using the International nuclear and radiological event scale. The rating, therefore, is still not available and on the website of CLP, Daya Bay is a frequent winner of awards in the Safety Challenge Competition organized by Electricite de France (EDF).¹¹⁷

Need to Dispose of Radioactive Wastes

China has put forward its radioactive waste management policy as follows: the radioactive wastes shall be handled in the most proper way to protect human health and surrounding environment. That's why it is crucial for each nuclear facility or practice to construct the radioactive waste management facility when every new project is launched. The State has the overall control over the radioactive waste process from generation to final disposal. For discharged gaseous and liquid radioactive waste, they must be treated in accordance with the standard requirements. For solid radioactive waste, they should be classified before being disposed.¹¹⁸

116 □□□□□□□□□□□□□□□□, , Hongkong, 18 Sep, 2008

117 National Nuclear Safety Administration (NNSA). Nuclear Safety Annual Report

118 For more details of the regulation, please refer to Forum for Nuclear Cooperation Asia (FNCA) Consolidated Report (China), Updated as of March 2007. Part 3.2.1 mainly deals with the RWM policy in China. Available at: <http://www.fanca.mext.go.jp/english/index.html>

With the rapid development of the Chinese nuclear industry, safe disposal of high level radioactive waste is no doubt a challenging issue for the sustainable development of nuclear energy. It is estimated that, by 2015, there will be 2000 tons of spent nuclear fuel, which means a pilot reprocessing plant must be put into operation at that time. The studies for the disposal of High Level Waste (HLW) in China started in 1985 and the *R&D Guidelines for Geological Disposal of High-Level radioactive waste*, jointly published in 2006 by the CAEA, the Ministry of Environment Protection and Ministry of Environment Protection and the Ministry of Science and Technology, set the objective to build a Chinese high level waste repository by 2050.

Table 22: Three-step long-term plan for geological disposal of HLW in China

Step	Period	Milestone
Step 1 : Laboratory studies and site Selection for HLW repository	2006-2010	Preliminary reposition sites should be preliminarily selected with preliminary site characterization completed. A site for underground research laboratory (URL) is confirmed and its construction is completed. Preliminary technical capabilities in major areas are established through laboratory studies.
Step 2 : Underground in-situ tests	2021-2040	Completion of site characterizations and confirmation of the final repository site. Completion of the most in-situ tests in the URL and establishment of technical capability for construction of the repository established. Completion of detailed repository design.
Step 3 : repository	2041-2050	Completion of the repository construction around 2050. The demonstration for HLW disposal with vitrified HLW.

Source: Wang, 2010. High-level radioactive waste disposal in China: update 2010, *Journal of Rock Mechanics and Geotechnical Engineering*, Vol. 2, No. 1, pp.1-11.

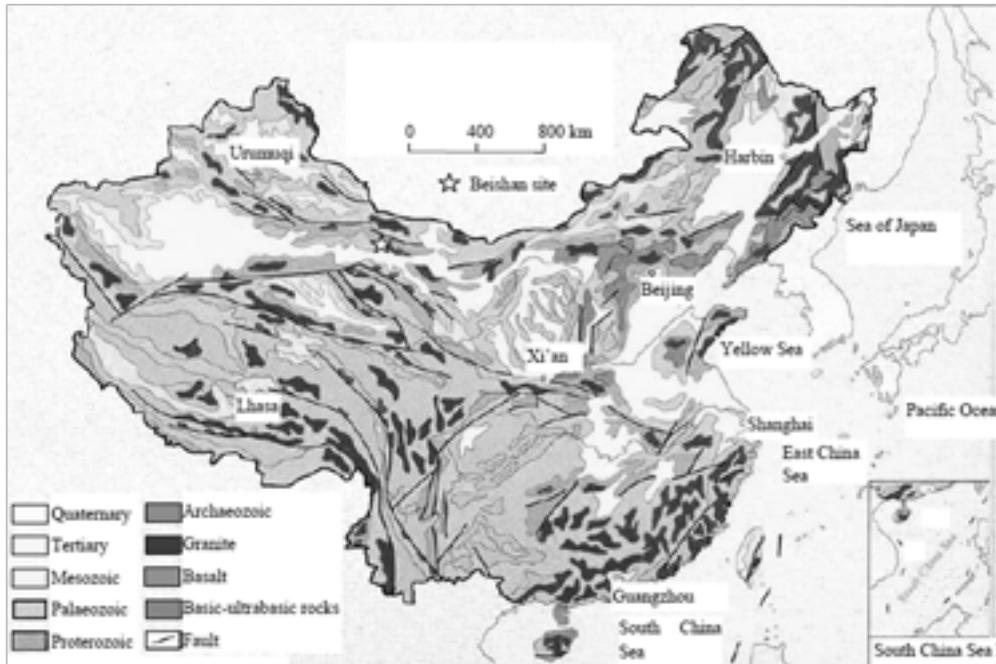


Figure 23: Location of Beishan site in northwest China

Source: Wang, 2010. High-level radioactive waste disposal in China: update 2010, *Journal of Rock Mechanics and Geotechnical Engineering*, Vol. 2, No. 1, pp.1-11.

According to the guidelines, a three-step long-term plan was clarified and Table 22 shows the target of each phase. After more than a twenty year long site selection process, the Beishan area in Gansu Province was considered as the most suitable area among the 21 potential candidate areas, tending to be the base of China's HLW repository in the future.

However, according to Zhao Wenyan, an official at the China Isotope and Radiation Association, some radioactive sources, such as ^{60}Co has been commonly used in China since 1950 due to low regulatory requirement and even though the government has spent lots of money on handling the disposal of used radiation sources, the spending is still not enough compared to the large amount of disposed wastes throughout the country.

4.9.5. The Danger of Proliferation of Nuclear Weapons

The Nuclear Non-Proliferation Treaty (NPT) guarantees peaceful use of nuclear technology, and in May 1992, China formally acceded to the Treaty. Under the term of NPT, China became recognized as one of the world's five "nuclear weapon states". On 3 December 2003, the government issued the White Paper on China's Non-Proliferation Policy and Measures, indicating specifically the non-proliferation policy and regulations in the country. China promises to utilize nuclear power only for peaceful purposes under the supervision of IAEA and of course, the nuclear technology won't

be transferred to the third party without the consent of Chinese government.¹¹⁹

Moreover, China stated the No-First-Use (NFU) policy in 1964, promising “not be the first to use nuclear weapons at any time or under any circumstances”. Officials proclaim that the country has stuck to a modest defensive nuclear policy and will be devoted to the nuclear disarmament.¹²⁰ However, China still faces the accusation of refusing to disclose details on its nuclear weapons, as well as assisting various countries and regions to manufacture nuclear weapons since 1985, despite China’s promise not to assist third parties to acquire the bomb. The Nuclear Control Institute in Washington, D.C accused China of “not living up to its non-proliferation promises” in a document presented to U.S. Congressional Subcommittee on Telecommunications, Trade and Consumer Protection, criticizing that China did not stop its proliferant exports.¹²¹

4.9.6. Public Acceptance of Nuclear Power Plants in China

Public acceptance has a huge impact on the development pace of nuclear technology worldwide, which means how people are aware of and view the potential risk of NPP will inevitably impel or retard the execution of NPP construction or even the overall plan-making process.¹²²

In order to meet the increasing energy demands to achieve rapid economic development and the urgency of reducing the GHG-emission, the country is now dedicated itself to realize the blueprint of nuclear technology and there is no doubt that it will have an active expansion in China as various driving factors tend to present it the very best option for sustainable development, unless there was a major domestic catastrophe involving NPPs. Currently people trust the regulation and supervision by China National Nuclear Safety Administration (CNNSA), so that nuclear power facilities in China go through strict process before being put into commercial use. On behalf of the state, the organization’s four monitoring stations in Shanghai, Shenzhen, Chengdu and Beijing are responsible for the day-to-day supervision of the nuclear safety activities (Zhou and Zhang, 2010).

In recent years, China pays huge attention to indigenous R&D and over the next ten years, more than one trillion RMB (15 billion USD) will be injected as direct investment to accelerate China’s nuclear technology development¹²³. Currently, three of the reactors, Qinshan Phase II 1, 2, 3, were indigenously designed and the country has basically mastered generation II nuclear technology. China is now working on its 4th generation nuclear reactor technology, which can efficiently reduce the consumption

119 Ministry of Foreign Affairs of the People’s Republic of China. 2005. *Implementation of the Treaty on the Non-Proliferation of Nuclear Weapons Report*. <http://www.mfa.gov.cn/eng/wjb/zzjg/jks/kjfywjt195938.htm>

120 Rong Yu, March 2004, China’s Nuclear Policy. Only India (a non-NPT state) has adopted a NFU policy among the other nuclear weapon possessing states. The Soviet Union and People’s Republic of China have a mutual treaty of NFU against each other.

121 Please refer to the website of Nuclear Control Institute (NCI) for the complete document: <http://www.nci.org/index.htm>

122 Refer to Section 5.1. on public opinion internationally for further discussion of public opinion surveys.

123 For more statistics, please refer to *Great leap forward for China’s nuclear investment in the next ten years*. 21st Century Business Herald 20 May, 2010

of uranium and minimize the production of radioactive wastes. The achievements of the first fourth-generation nuclear reactor enhanced people's confidence in the nation's power and thanks to the huge amount of fabulous news report, the public uphold a cheerful emotion for the latest achievement.

Being aware of the potential threat of large-scale radiation leak, there are some anti-nuclear voices. However, compared with the prosperity of anti-nuclear organization in western countries and anti-nuclear movement in Japan, the domestic objection voice is still very weak, especially in P.R. China.

In 2006, a well organized anti-nuclear petition campaign was launched as three nuclear power stations were proposed in Shandong Province. A local NGO, Ocean Protection Commune, spread an open letter to Premier WenJiabao, expressing the public opposition to the construction of nuclear power stations alongside the famous Silver Beach in Weihai, and urged the government to promote renewable energy to meet the domestic energy needs. Also, another anti-nuclear campaign burst out in Hunan in July 2006, as the provincial government signed an agreement with CNNC to launch the first NPP project in inland of China.¹²⁴

Of course, the nuclear disaster at Japan's Fukushima Daiichi Nuclear Power Station has raised questions about the future of nuclear power in Asia, and several protests burst out in Hong Kong and Taiwan. Three months exactly after the Fukushima nuclear leak accident, one hundred protestors gathered at Tsin ShaTsui, the most downtown area of Hong Kong, asking politicians to support the abolition of nuclear power and make a nuclear free-zone in Asia.¹²⁵ In Taiwan, thousands of people protested against nuclear energy on 31 April 2011, in response to the public fear triggered by the Fukushima Daiichi nuclear accident. The rallies took place in various major cities in Taiwan, and undoubtedly, nuclear energy will become an action target for environmentalists and right activists groups.¹²⁶ But due to various political and economic reasons, we can hardly find any reports of reaction in mainland China to the Fukushima accident, and the active public engagement, which is supposed to be beneficial to the policymaking, is still rare on any controversial topic.

There is no doubt that China will keep on developing its nuclear technology in the future since the reduction of GHG and meet the demands of electricity are two main goals for the country. But more actions should be taken to enhance the indigenous R&D of nuclear technology, to release people's concerns of the safety issues. More attention should be paid to public participation and a more mature policy system is in a urgent need to be launched to future formulate the whole industry.

4.10 Nuclear Energy Options for Indonesia

Indonesia is situated between the Pacific and Indian Oceans, between the continents of Asia and Australia. It consists of nearly 18,000 islands and is the fourth largest country in the world in terms of population. A large portion of the country lies within the

124 2007. *China's Emerging Anti-Nuclear Movement*. Nuclear Monitor. <http://www.nirs.org.mononline/nm663.pdf> (Accessed 20 August, 2011)

125 2011. *Anti-nuclear demonstration in Hong Kong*. <http://worldlabour.org/eng/node/475> (Accessed 20 August, 2011).

126 2011. *Talk of the day -- Anti-nuke rallies* http://focustaiwan.tw/ShowNews/WebNews_Detail.aspx?ID=201105010007&Type=aTOD

Pacific Ring of Fire, a 40,000 km zone that is seismically active due to subterranean faults arising from plate tectonics, movement and collision of the Indo-Australian, Indo-Chinese, Pacific and Philippine crustal plates. Thus, 90 percent of the earthquakes and volcanoes that occur are in the 7000 islands, which are inhabited, of which Java, Bali and Sumatra are highly prone to geological upheavals. Thus, a question that can be asked is whether such a country can undertake the risk of running NPPs? Ethically speaking, should a nation hold back its struggle for green power to satisfy its energy crisis, against the backdrop of impending natural disasters? In September 2010, about 1,100 people died due to a 7.6 magnitude earthquake in west Sumatra. Another 81 people were killed, 350,000 buildings collapsed in Yogyakarta and 45,000 in West Java in an earlier earthquake. The country's energy situation is of a serious concern in cities like Surabaya and Jakarta as it battles repeated blackouts due to earthquakes and volcanic activity. People living in remote parts of the islands are frequently deprived of electricity and live in darkness.

Indonesia has about 30 gigawatts (Gwe) of power in its national grid and needs an additional 5GW every year in the near future. From 1980 to 2006, the last year for which figures are available, annual electricity consumption rose dramatically from 11.299 to 110.71 billion kWh according to IAEA, and continues to rise at an alarming rate. The country's first fast-track power program in 2006 was designed to deliver 10,000 megawatts to the grid. However, it is years behind schedule and has been delayed due to low pricing of power, fluctuating coal prices, the difficulty of convincing Chinese export banks to provide loans against absence of state guarantees, and additional problems like multi-ministry delays on permits, permissions and procedures coupled with the negative impact of corruption and inefficiency. Coal producers are facing the dilemma of selling to an energy-starved internal market in a country without efficient roadways, ports and pipelines versus exporting coal and gas to good profits abroad. The Asian Development Bank (ADB) has suggested that the country must invest 4 million US dollars in the power sector to make the economy more competitive.

The national energy issued in Indonesia is in Law Number 30, Year 2007, on Energy. Article 2 of the law states that, *"Energy is managed based on the principles of benefit, rationality, equitable efficiency, increased value added, sustainability, community welfare, environmental conservation, national resilience, and emphasizing the integration of the national capability."* The policy is reflected in maximizing the use of new and renewable energies, especially geothermal, hydro-energy and bio-fuels, before deciding to use the nuclear energy. The use of the nuclear energy would be the last option. *"The last option, however, does not mean that nuclear is not being prepared. It will remain being prepared; we are now still maximizing the use of other new and renewable energies such as geothermal, hydro-power, and bio-fuels which have a big potential for development,"* said Luluk Sumiarso, Director General for Renewable Energy and Energy Conservation.

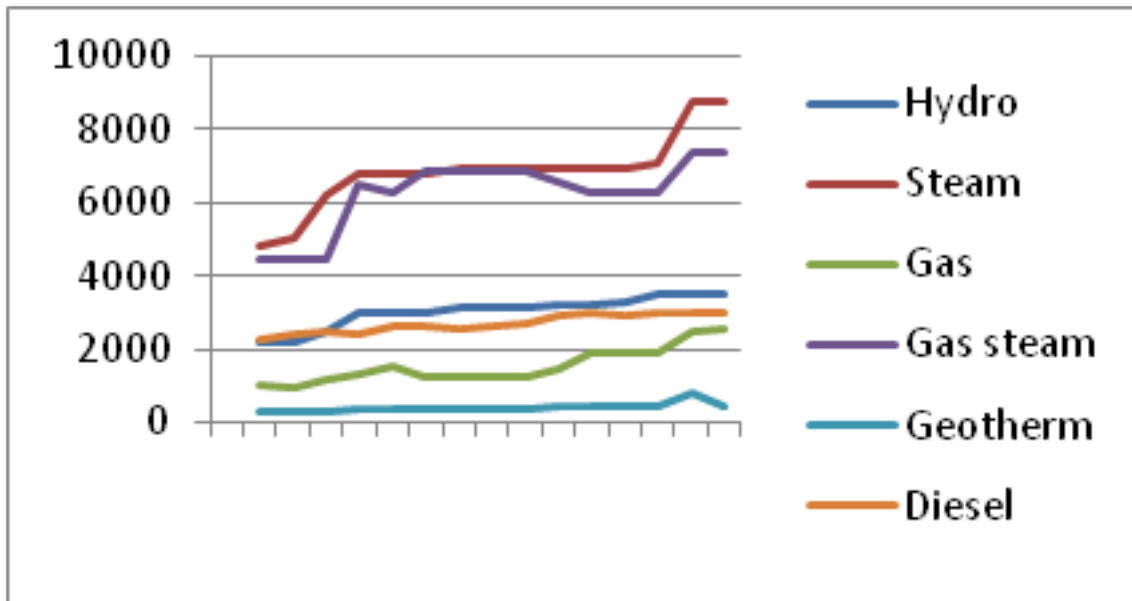


Figure 24: Installed electricity based on types of electricity generation in Indonesia from 1995-2009

Source: Badan Pusat Statistik Republik Indonesia; bpsHQ@bps.go.id

The plan to build NPPs (PLTN, *Pembangkit Listrik Tenaga Nuklir*) would continue to go ahead with the principle of conformity, readiness, and safety. *"The use of nuclear energy needs a political decision,"* Luluk said, adding that the case of the nuclear accidents in Fukushima, Japan, would be a lesson for Indonesia. The government is revising the rules of new and renewable energy utilization in the energy mix that was previously targeted at 17 percent to be 25 percent in 2025. *"The revision of the energy mix is made by looking at both nuclear and non-nuclear. The government would also make every effort to speed up the utilization of the new and renewable energy. New energy technologies consist of coal bed methane (CBM), gasified coal, hydrogen, liquefied coal, and, nuclear while renewable energy technologies cover geothermal, bioenergy, hydro, solar wind and ocean energy."*

The government is currently carrying out the construction of the second phase 10,000 MW power plant with most of its energy coming from geothermal and hydro-power. It is the target of the government that the geothermal capacity will increase by 2,000 MW in 2012 and rises to 5,000 MW in 2014 as the country's geothermal potential is 29,000 MW. Aside from geothermal energy, Indonesia is also reviewing the development of bio-fuels. The overall target of new and renewable energy use by 25% in 2025 is the so-called 25/25 vision of energy in Indonesia.

Forced by strong opposition from the local population, the government has decided to postpone building a NPP in the Muria Peninsula in Central Java and is now focusing its attention on Bangka Belitung (Babel) Province, off Sumatra's east coast, as the future site of such an electricity generating facility.¹²⁷

127 Andi Abdussalam, ANTARA News, 7 July 2011.

Studies are in progress to build two NPPs in Babel with a combined capacity of 10,600 Megawatts. NPPs are expected to supply and meet 40 percent of the need for electricity in Sumatra, Java and Bali. *“The nuclear power plants are expected to become operational by 2025 or 2030 and hopefully they will meet 40 percent of the electricity need in Sumatra, Java and Bali,”* according to the Governor of Bangka Belitung province Ekon Maulana Ali. According to plan, the government will build two units of NPPs with a combined capacity of 10,600 MW. One will be built in West Bangka district with a capacity of 10,000 MW and another one in Permis, South Bangka, with a capacity of 600 MW.

“The central government hopes that by 2013-2015 the preparatory and planning stages would have been completed. If the site test results show that it is feasible and appropriate for construction of a NPP then the government would continue the project,” he said. However, the governor was sure that the project would go on. *“The plan to build nuclear plants in South and West Bangka to generate electricity would be implemented,”* he said. The NPP construction plan was a central government policy which had been included in its master plan designed to accelerate and expand development. The government intends to develop a NPP as another electricity source to meet its national need for power supplies amid depleting oil and gas reserves. Fossil fuel reserves such as coal, oil and gas were being depleted because they were not only used domestically but also were exported in large volumes. Hydro power sources are also less reliable because of weather anomalies and environmental damage.

Therefore, alternative energy and nuclear power is considered important to develop to meet the high need for electricity. However the construction of a NPP would still take a long time as the government was still in the process of surveying it and carrying out site tests in Babel. For the construction of one unit with a capacity of one Gigawatt, a fund of IDR 35 trillion (USD 4 billion) was needed. Babel was planning to construct two units which would be located in Muntok (West Bangka) and Permis (South Bangka). *“With the required investment of IDR 70 trillion, the government should not be worried. There are many foreign investors interested in the construction,”* the governor said.

The Head of National Nuclear Power Agency (BATAN) Hudi Hastowo said Babel was the most suitable site for the construction of a nuclear plant in Indonesia. The Batan Chairman said that his agency would continue to apply various results of its nuclear scientific research in the locations that have been agreed by the Babel regional government. Bangka Belitung was the most suitable place for the development of a NPP from the aspect of its geological structure reinforced with hard granite rocks and strong electricity absorption capacity that could transmit power to Sumatra and Java. It is considered a low risk earthquake area free of tsunami threat.

A survey conducted by BATAN in May-June 2011 revealed that 35 percent of respondents in Babel supported a NPP, 30 percent of the respondents rejected the plan, while 30 percent have yet to decide.¹²⁸

In light of the above problems Indonesia strives to embrace nuclear technology as

128 The survey was of 500 respondents from various segments of people in West Bangka and South Bangka areas.

a solution to stave off its power crisis that affects its ever-increasing population. The Nuclear Energy Regulatory Agency (Bapeten) and the National Atomic Energy Agency (BATAN), the two agencies which are jointly responsible for overseeing the country's nuclear activity, in 2002-2003 had also proposed nuclear plant sites in the Muria peninsula on the north coast of Central Java despite repeated protests from the public.

Despite political turmoil and a weak regulatory framework, the Indonesian government seems determined to go ahead with the project that will supposedly provide 4000 MWe to alleviate problems arising due to green-house gas emissions from coal-fired plants, as well as supply electricity to the industrialized region around Jakarta. An overruling reason for investing in this expensive energy option seems to be driven by the fact that nuclear power manufacturers (and their governments) in countries like Japan, China, Korea and France are looking at export markets like Indonesia to underwrite their cost of domestic production.

Nevertheless, the long term viability of such a project is questionable under the threat of natural calamities and protesting ethnic groups against leaders need to take on both biocentric and ecocentric viewpoints instead of adopting a purely anthropocentric approach. Awareness of the risks and benefits need to be debated so as to avoid the misuse of nuclear technology. Externalities associated at every stage of nuclear power production need to be assessed to address issues of economic feasibility, environmental implications and the well being of the citizens. Under such circumstances it is necessary for the government to adopt a pluralistic approach to the issue of energy crisis by setting up dialogues between stakeholders namely, state representatives and a cross-cultural group of citizens to arrive at sound decisions that would benefit the country, globally and its people.

4.11. Nuclear Energy Development in Kazakhstan

Kazakhstan's government is planning extensive development of nuclear energy in the country, considering the achievements in the uranium mining industry. After the collapse of the Soviet Union, Kazakhstan was left with the stagnating nuclear industry with falling profits; consequently, the reconstruction of the industry was required. In 1997 by the Decree of the President of Kazakhstan the National Atomic Company, *Kazatomprom*, was established with the main goal to restore and develop the nuclear industry in Kazakhstan.¹²⁹

The decree emphasized the importance of the atomic industry for the development of the country and put it as one of the strategic interests of the country. *Kazatomprom* was declared a 100% state-owned company which should deal with exploration, research, mining, export and trade of uranium, operating NPPs, and to cooperate with the industries and companies involved in the nuclear industry field (Nuclear Threat Initiative, 2003). Kazakhstan was able to develop nuclear industry field to the competitive level in global market in a short period of time. Within 8 years the national

129 Nursultan Nazarbayev, 2011. The annual message to the people of Kazakhstan [online]. Akorda. Retrieved from: http://www.akorda.kz/ru/speeches/addresses_of_the_president_of_kazakhstan/march_2006. Accessed on 3 June 2011.

company *Kazatomprom* not only revived the nuclear industry from the crisis but became one of the key players in the sphere of global uranium production. This result could not be achieved without consistent commitment and a strategic plan of action from Kazakhstan's government as well as foreign investments. However, if after the collapse of the Soviet Union and first decade of independence the main strategy of the country in general and the nuclear industry in particular was to overcome the crisis and stagnation, the goals for the near future for the country are far more ambitious with the desire to play a leading role in such spheres as the nuclear industry.

The development of nuclear energy industry in Kazakhstan could be divided into several sections, uranium mining, completion of the nuclear fuel cycle and construction of a NPP. The government projects to achieve several goals in the field of nuclear industry in a relatively short period of time by 2020. The commitment of the government to develop and secure the position of Kazakhstan as an important player in uranium production sphere was emphasized by high officials. President of Kazakhstan Nazarbayev (2006) has emphasized in his annual messages to the people of Kazakhstan to make a target of achieving rapid industrial growth and economic prosperity. The administration of Kazakhstan has developed a strategic plan of development "Kazakhstan-2030", beyond the plan Kazakhstan-2020 for economic development of the country. President Nursultan Nazarbayev in 2006 has put a target for Kazakhstan to be on the list of the 50 most competitive countries in the world. However, for the fulfillment of all the plans for modernization and industrial growth, huge supplies of energy resources are needed. Subsequently, the development of the nuclear energy sector seems to be a thoroughly calculated act and is one of the obstacles for ensuring the targeted industrial growth.

From one perspective the development of nuclear energy sector in Kazakhstan could be considered to be ambitious due to the scale of development and time constraints; nevertheless, Kazakhstan has all the required resources to fulfill its goals. Kazakhstan's nuclear energy sector is run by a state-owned company *Kazatomprom* which is responsible for the development of nuclear industry and international agreements between Kazakhstan and other countries in nuclear sphere. First of all it is necessary to keep in mind natural conditions for nuclear power in Kazakhstan. The country possesses 15 % of the world's uranium resources, which makes it the third country in the world in terms of uranium reserves (WNA, 2010). In 2009, Kazakhstan was the world's largest uranium producer with 28% of world production; however, *Kazatomprom* expressed their willingness to increase this figure to 30% of world's uranium production by 2015 (WNA, 2010). Kazakhstan was consistently increasing the production of uranium from 2001 to 2009 starting from 2,000 tonnes to 14,020 tonnes of uranium per year (WNA, 2010). The target of becoming the world's largest producer of uranium was achieved due to the exploration and construction of new mines, upgrades and extension of nuclear fuel production (Vinokurov, 2008). Consequently, the ambition of becoming the largest uranium producer was fulfilled in the matter of 10 years.

The next ambitious goal of Kazakhstan is to develop full nuclear fuel cycle on its territory in order to become independent from Russia. Currently, Kazakhstan is operating uranium mining and fuel pellet production on its territory, while conversion and enrichment, as well as fuel rods production is done on Russian territory. The issue

of Kazakhstan's commitment to nuclear nonproliferation and financial constraints of developing all the facilities for full nuclear fuel cycle in the recent time made it easier for Kazakhstan to collaborate with Russia (Kassenova, 2008). The prospect is to establish a common enrichment facility with Russia which could be used by *Kazatomprom*, with the restriction for Kazakhstan's experts' access to enrichment technology but to operate the process itself (Kassenova, 2008). Furthermore, Kazakhstan and Russia are promoting the use of International Uranium Enrichment Center (IUEC) in Angarsk, Russia for the access to nuclear fuel by other countries.

Although Kazakhstan is collaborating with Russia on nuclear fuel cycle stages, it also diversifies its partners in the nuclear energy sphere. Thus, for instance, *Kazatomprom* bought a 10% share of Westinghouse Electric, a leading nuclear reactor producer, in 2007 (Vinokurov, 2008). From this deal *Kazatomprom* gained access to world's nuclear fuel markets as well as technical assistance in the production of fuel assemblies (Kassenova, 2008).

Kazakhstan is actively negotiating with Japan on nuclear fuel exports, not only of uranium but also fabricated fuel assemblies (WNA, 2010c). Kazakhstan would like to supply 40% of the Japanese need for natural uranium and fabricated fuel from 2010 (Muzalevskiy, 2010). Japanese partners are engaged not only in the uranium exports agreements but also technical assistance to the National Nuclear Center and research conduction of the feasibility of the nuclear energy sector development in Kazakhstan (WNA, 2010).

The cooperation of Kazakhstan with China in the field of nuclear industry is also increasing and developing. In 2006 China's Guangdong Nuclear Power Group Holdings (CGNPC) signed an agreement with *Kazatomprom* for Chinese participation in Kazakh uranium mining projects and Kazakhstan's investment in China's nuclear industry (WNA, 2010c). In addition, the agreement makes Kazakhstan the main supplier of uranium to CGNPC overtaking French company *Areva* and they will start selling to China nuclear fuel by 2013 (Kassenova, 2008).

The next ambition is to produce domestic nuclear power and meet the needs of electricity. From 1973 to 1998, Kazakhstan (2002) had operated its only nuclear reactor in Aktau which was dedicated for water desalination and electricity generation. Since the date of expiry in 1998 the reactor was closed, so from that time Kazakhstan did not operate any nuclear reactors on its territory. However, for the full realization of nuclear energy development it is required to start constructing and operating of at least one NPP. The project is to start construction of a NPP in Aktau in 2011 based on the Russian type of nuclear reactors (WNA, 2010), to meet the energy needs of the western part of Kazakhstan which now relies on the supply of electricity coming from Uzbekistan (Kassenova, 2008). There are also projects to build NPPs near Lake Balkhash for electricity supply to Almaty city (WNA, 2010c). The poor supply of electricity and increasing demand for it makes energy supply a major concern for government officials. Just in the southern part of Kazakhstan the deficit in electricity will be 1.9-2.0 billion kWt per hour by 2030, although this figure should be achieved with the introduction of new South-Kazakhstan State District Electrical Plant (Kazakhstan, 2002). 80% of the electricity sector of Kazakhstan is dependent on the heat-and-power plants, which

cannot meet the domestic demand for the energy (Vinokurov, 2008). Moreover, the electricity grid of Kazakhstan was built during Soviet times; hence, after getting independence the northern and southern parts of Kazakhstan were not connected by a common electricity grid. Consequently, it appeared that the largest producer of energy is Pavlodar oblast in north of Kazakhstan, whereas the highest consumption is coming from the southern part (Vinokurov, 2008).

The goals of Kazakhstan in nuclear energy development are both ambitious but yet attainable with government commitment and appropriate investment. Kazakhstan already has established connections with foreign partners on the development of nuclear industry and attracted investors into this field. Moreover, Kazakhstan is also recognizing the need for the diversification of domestic energy supply in order to meet the growing deficit of electricity in domestic market. However, the drawbacks of nuclear energy development in the case of nuclear accidents should not be omitted. The security and guarantee systems of nuclear energy facilities should be thoroughly analyzed by experts and policy-makers in Kazakhstan, learning from both experiences of Chernobyl and Fukushima. Even though the location of future nuclear power plant in Kazakhstan is tentatively decided still necessary preliminary protectionist measures should be undertaken, such as the assurance of substantial distance of NPP from local residential areas, security systems against natural disasters, and elimination of human error that could cause nuclear accidents. Moreover, the development of the nuclear energy sector in Kazakhstan requires not only the creation of nuclear energy facilities, but also an extensive knowledge-base and highly qualified personnel, including nuclear engineers, administrators, workers, and emergency personnel.

4.12. Philippines Experience

A case of lack of public involvement and accusations of use of ethical principles by political parties concerns the nuclear power project in the Philippines. The growing power crisis in the country led to rapid decisions being made by changing political parties thereby affecting both the country's economy and the people of South Luzon. The nuclear facility at Bataan peninsula that was built at a cost of USD 2.3 billion, has not produced a single watt of electricity while tax-payers are still paying.¹³⁰ The nuclear plant, upon inspection by an international team of experts, was deemed unfit for operation since it was built in a geologically restive area prone to earthquakes, as well as in close proximity to Mount Pinatubo, a volcano which erupted in the 1990s. After being moth-balled for decades, the government's decision to decommission the nuclear plant was met with strong public resistance as dismantling would cost at least another USD billion of taxpayer's money. The hasty decisions of subsequent governments has eventually led to a collaboration with foreign investors with an intention to convert the nuclear facility to a fossil fuel plant, reinforced by the Fukushima disaster. Proposals for small-scale wind and flow-through mini-hydro power plants as cheaper and safe sources of electricity have also been suggested by experts at the

¹³⁰ The construction of the nuclear reactor was started in 1976 and completed in 1984 at a cost of USD 2.3 billion. It houses a Westinghouse light water reactor (PWR) designed to produce 621 Megawatts of electricity. It is claimed that the interest payments cost approximately USD155,000 a day, Olea, R.V. 2009. Revival of Bataan Nuclear Power Plant a Source of Corruption? bulatlat.com <http://bulatlat.com/main/2009/01/31/revival-of-bataan-nuclear-power-plant-a-source-of-corruption/>

behest of the Philippine government. However, the people of Central Luzon have expressed resentment as they feel that it is not them but foreign investors and the government who will benefit from such endeavours.¹³¹

131 See Olea, R.V. 2009, *ibid.*

5. Ethical Aspects of Nuclear Energy

While the ethics of nuclear energy technologies were discussed earlier, this section discusses ethical aspects of nuclear energy which transcend the technology itself. These aspects often figure prominently in mainstream media and current events, making them widely discussed. These aspects include public perception of nuclear energy, community engagement, nuclear proliferation, international relations, nuclear agreements, and nuclear justice and equity (including a rights based approach). The section concludes with a brief subsection on the application of ethical principles.

5.1. Public Opinion About Nuclear Energy

In 1993 the International Bioethics Survey posed questions on knowledge of nuclear energy, and about its perceived benefits and risks (Macer, 1994). In all countries of the International Bioethics Survey there was a positive view of science and technology, it was perceived as increasing the quality of life by majority in all countries. Less than 10% of respondents in all countries saw it as doing more harm than good. When asked about specific developments concerning technology, including in vitro fertilisation, computers, pesticides, nuclear power, biotechnology and genetic engineering, both benefits and risks were cited by many respondents (Macer, 1994). Among the six different technologies respondents were most negative towards nuclear power, followed by pesticides. Hong Kong students also expressed specific concern due to the recent opening of a nuclear power reactor in Daya Bay close to the border with public debates on safety standards. People show the ability to balance benefits and risks of science and technology, and most do not have a simplistic view of science and technology.

In response to the question, "Do you personally believe **nuclear power** is a worthwhile area for scientific research? Why?..." 65% of respondents in India, 64% in Japan, 61% in Thailand, 58% in Israel, 55% in Russia, 54% in Australia, and 47% in New Zealand, viewed scientific research on nuclear power as worthwhile. 43% of New Zealand respondents answered negatively to the same question, followed by 30% in Australia and Israel, 27% in Thailand and Russia, 20% in Japan, 19% in India and 18% in Russia. Some respondents were uncertain, given by 18% of respondents in Russia, 16% in Australia Japan, and India, and 12% in Thailand and Israel.

The same question was asked among high school teachers in Japan, Australia and New Zealand, and they were all more positive than the public samples for their countries. 78% of Japanese social science teachers, 75% of Australian biology teachers and Australian social science teachers, 73% of Japanese biology teachers, 62% of New Zealand social science teachers and 60% of biology teachers, thought that nuclear power was a worthwhile area of scientific research. University student samples were however generally less positive than the public in these countries.

The further question "Do you have any worries about the impact of research or applications of nuclear power? How much? Why?" had four options for reply, "Worried

a lot, some worries, a few worries or no worries". The percentages of respondents who were worried a lot about research and application of nuclear power were 53% in New Zealand, 52% in Russia, 48% in Australia, 35% in India, 32% in Japan and 31% in Thailand. The respondents with some worries were 32% in Thailand, 31% in Israel, 25% in Japan, 23% in Russia and India, 20% in Australia and 19% in New Zealand. It is interesting to look at the small percentages who said that they had no worries, which were 23% in India, 16% in Australia, 15% in Japan, Thailand and Russia, 12% in New Zealand, and 8% in Israel. We can say that few persons have no worries about nuclear power, as the word is associated with danger.

The samples of high school teachers reveal that although they saw more benefits from nuclear power as a worthwhile area of scientific research, they also had more worries about it. 55% and 54% of New Zealand social science and biology teachers, respectively, had a lot of worries, along with 45% of Australian and Japanese social science teachers, 43% of Japanese and 42% of Australian biology teachers. Less than 10% of any sample had no worries, which was less than all public samples.

The respondents gave many interesting comments in response to the open questions, and these were categorised (Macer, 1994). In response to the question "Do you personally believe nuclear power is a worthwhile area for scientific research? Why?... ", some example comments (and the categories they were assigned to) were:

"To invent material that can be produced in Japan. It has a power which is indispensable for our lives." (Economy)

Improved knowledge leads to greater knowledge and therefore greater safety. " (Scientific knowledge)

We stand to gain a better understanding of the benefits or disadvantages of each area. " (Scientific knowledge)

"It will contribute to the improvement of life." (Humanity)

"To conserve future resources/reduce CO₂ emissions." (Good for the Environment)

"Replace fossil fuel consumption." (Good for the Environment)

The most common reason given by 31% of Indians and 21% of Thai respondents was that it was worthwhile for energy, for example:

"Possible ultimate power source."(Energy)

"Inevitable future power source." (Energy)

"Especially fusion power to conserve fossil fuels." (Energy)

"We have to keep the limited resources for our descendants for a long time."(Energy)

About 10% of people gave a reason that it was helpful if we were careful, for example:

"It can be used to produce benefits. (All can also be misused to produce harmful results.)"(Help if careful)

"We probably can't run our world without them now, but they must be as safe as possible." (Help if careful)

"Improves safeguards and 'safe' disposal of wastes, not nuclear proliferation/weaponry."(Help if careful)

"I think there is no harm to research it if humans utilize them correctly, based on a proper view of ethics." (Help if careful)

About 4% of people gave a reason that it was bad for the environment, for example:

"Not to cause a bad effect on the environment." (Bad for the Environment)

"Mainly "no" because of my fear that animals may be abused in the process or in the end. Or in the case of genetic engineering that the whole job is not done properly, of disastrous consequences in future generations. Also I don't trust the powers that be not to abuse their knowledge." (Insufficient controls / Danger of misuse)

"We can't control what we have now." (Insufficient controls / Danger of misuse)

"No one should have the power or materials to wipe out so many people." (Insufficient controls/ Danger of misuse)

The most common reason given by about one fifth of the respondents was that it was dangerous, for example:

"It is far too dangerous but further development may change this, who knows?" (Danger / harmful)

"Natural energy is preferable. Use of nuclear power is dangerous." (Danger / harmful)

"The problem is how to safely use things which are essentially dangerous." (Danger / harmful)

"We have to research on it including disposal of wastes." (Danger / harmful)

"I believe in nature's way and man's interference in most of these material things will eventually become the downfall of all mankind." (Playing God / Interfering with Nature / Ethics)

"Dangerous - cancer." (Causes human disease)

"Perhaps yes to perfect process (leakage dangers), don't need in NZ." (Don't need / waste of money)

"Because I don't know enough about it." (Unknown area / don't know)

The respondents also gave a number of comments about their worries, in response to the question "Do you have any worries about the impact of research or its applications of these scientific discoveries and developments? How much? Why?.." The frequency of the concerns was similar, with some more specific reasons, as below:

"Spiritual knowledge insufficient to cope with the consequences." (Interfering with Nature / Playing God)

What repercussions come from it. (Fear of unknown / Feeling)

"In all cases because our mastery of science is not matched by our care, foresight, and ethical judgement in using the technologies." (Insufficient control)

"Dangers of poor control." (Insufficient control)

"I think there are many things which scholars keep in secret." (Insufficient control)

"A small accident may have large and serious consequences." (Disaster / Harmful (Both to humans and environment))

"Disposal of wastes and counter measures for accidents are insufficient." (Disaster / Harmful (Both to humans and environment))

"Until inventions, scientists et al. can clean up the dying forests, ozone depletion, nuclear

waste proliferation, and other environmental stupidity, we're wasting precious time and resources if we pursue other "interesting" fields." (Ecology / Environmental harm)

"Nuclear waste going into environment is/can be damaging." (Ecology / Environmental harm)

"Power companies push this for profit reasons." (Waste / Don't Need)

"In wrong hands all these things could be a source of power." (Human misuse)

"Too early use of these technologies has the potential for major catastrophic results further ahead." (Human misuse)

"War tools, instead of peace tools." (Human misuse)

"The destructive powers and the overwhelming capabilities of it's use in a negative manner." (Human misuse)

"Because people might use it only thinking of their interests. I would like to take good care of the natural form, too." (Human misuse)

"I wonder the downfall of humans will be accelerated if the idea that science is almighty continues." (Human misuse)

"If humans control it at all, mistakes could happen." (Human misuse)

"You can't join research and application together. All research and discovery must be knowledge and all forms of knowledge must be good." (Can control / Limited use is OK)

"Some of these areas are not known to me but I understand the need to discover and develop as long as safeguards are maintained by a higher power." (Can control / Limited use is OK)

"The more we know the better we will understand." (Can control / Limited use is OK)

"Research is a different (neutral) area. Final application is a political decision." (Can control / Limited use is OK)

A question asking the respondents their knowledge of science and technology used three answers for the respondents: that they could explain it to a friend, had heard of it, or had not heard of it. Many public respondents said they could explain "nuclear power" to a friend, 52 % in Russia, 49% in Australia, 42% in New Zealand, 41% in India, 35% in Japan, 24% in Israel, and 23% in Thailand. The respondents who answered that they had heard of nuclear power (but could not explain it) were 75% in Thailand, 66% in Israel, 61% in Japan, 57% in New Zealand, 55% in India, 49% in Australia, and 47% in Russia. Less than 10% of respondents in all countries said that they had not heard of nuclear energy.

GlobeScan (2005) cooperated with International Atomic Energy Agency (IAEA) to analyse the resulted of six questions in 18 different countries: Argentina, Australia, Cameroon, Canada, France, Germany, Great Britain, Hungary, India, Indonesia, Japan, Jordan, Mexico, Morocco, Russia, Saudi Arabia, South Korea, and the United States.¹³² Overall 18 countries of the respondents, 34% of the respondents believed that countries with NPPs should use the ones they already have but not build new ones. Overall that means 59% of the public think new NPPs shouldn't be built. Using other words, 62%

¹³² They asked public respondents by person-person and telephone interviews conducted among 1,000 persons per country from 13 May to 25 August 2005. See http://www.iaea.org/Publications/Reports/gponi_report2005.pdf

were agreeable to retain their active NPPs. 28% believed that nuclear power is safe and that interested countries should build more NPPs.

However, 25% said that all NPPs should be closed down in the world as soon as possible and nuclear power is dangerous. The highest proportion of persons who believed that was 49% in Morocco, 41% in Jordan and 36% in Saudi Arabia. In Japan at that time only 15% thought all NPPs should be closed, with 12% in Republic of Korea and 16% in France. There was generally higher support the more educated the respondents, and among more men than women.

Regarding nuclear energy technology 39% overall supported its use to treat human diseases like cancer, 26% to generate electricity, 5% to support food safety, 5% to eliminate harmful insects, 4% to increase food production, while 10% said they supported all these applications equally. In Indonesia and Republic of Korea more than half of the respondents supported nuclear technology for electricity rather than for medicine (Globescan, 2005).

The Asahi Shimbun¹³³ conducted an international survey on public opinions in May 2011 regarding the Fukushima Daiichi NPP in the United States, France, Japan, Germany, Russia, South Korea and China. Three quarters (73%) of the Japanese respondents said they opposed building more nuclear power plants (NPPs) or expanding existing ones, and only 16 percent were in favour. Two thirds (68%) of French respondents were opposed to new construction with 29% in favour of new plants, similar to 64% of Korean respondents who opposed constructing NPPs whereas 30% of the respondents were in favour.

China is a country with active expansion of NPPs, but less than a half (46%) respondents were in favour of building new NPPs, and 52% of respondents were opposed. In the USA 46% of respondents supported construction of new power plants while 47% of respondents were opposed to the idea. In China 90% of the proponents of nuclear energy were in favour of new construction compared to 76% in the USA. However, more than 40% of the supporters of nuclear power in Republic of Korea, France, and Japan were opposed to expanding the existing or building new NPPs.

A question was asked, "What should be the future of nuclear power in their countries?" Only 32% of respondents in the USA and China said, "Nuclear power generation should be increased". Less than 10% of German, Russian, French and Japanese respondents, and only 13% of Korean respondents felt the same. In Germany, 81% of German respondents said "Nuclear power generation should be stopped", on the contrary in Japan, only 16% thought so.

When questioned about alternatives to nuclear power, 71% of French, 70% in Republic of Korea, 66% in Germany, 57% in Japan, and more than half in the United States and China, people thought wind and solar energy "should play the central role in future energy generation". In Russia, only 36% of people thought wind power or solar power should be central to energy policy, but that exceeded the 12% of respondents who saw the future in natural gas and the 16% supporting hydroelectric power. In Japan only 17 percent chose nuclear power, less than the public support in Germany at 19%.

In the Republic of Korea, 82% of respondents said they were very and somewhat

133 Asahi Newspaper, Japan, 2011 Survey finds wide gulf in global opinion on nuclear power, 9 June 2011. See <http://ajw.asahi.com/article/0311disaster/fukushima/AJ201106090571>

concerned over the Fukushima Daiichi accident. Similarly, in Russia, 80% said the same, followed by more than 70% in other countries except in the USA, where 61% respondents were concerned over the accident and 38% of respondents said that they were not concerned. 71% of Russian and Chinese respondents said that "safety of nuclear power generation can be ensured with the right technology and controls". A question was asked of the uneasy feeling towards the radiation that continues to leak out of the Fukushima. 83% of Chinese respondents, as well as 82% of in Korean respondents, and 70% of Japanese respondents were concerned.

The data from the surveys from 1993 to 2005 provide useful baseline data to study the impact on public opinion of the Fukushima accident. Balancing the benefits and risks of technology is an important indicator of ethical maturity of a nation. Let us consider a few country examples, however, it appears that there will need to be further information regarding public opinion. A significant reason for decline in public support is decline in trust in government assurances (Macer, 1994; Flynn, 2002), and as discussed in this report the lack of transparency in the worse accidents in Chernobyl and Fukushima will erode public trust in how regulatory authorities and companies fail to implement the assurances that have been made that they will be transparent.

China

In China, due to widespread national publicity, the public acceptance of NPPs remains quite optimistic, although as discussed above the Asahi Shimbun survey found 52% opposed to building new NPPs in May 2011. The reasons for the national policy were discussed in section 4.9, including the great domestic need for electricity-generation based on clean energy, the measures adopted to ensure the safe operation of NPPs, and the Chinese people's ardent wish to see the great leap of indigenous R&D. The Energy, Environment and Economy Research Institute of Tsinghua University has carried out research on public acceptance of nuclear technology in China from 2002 to 2006 and the results showed that, although the support rate for rapid development of NPP was quite low worldwide, in developed countries particularly, the public in China held quite supportive attitudes towards it. The statistics also revealed that from 2004 to 2006, the approval rate were higher than 80%. Compared with the 44% approval rate in 2001 in USA, nuclear energy enjoys high acceptability (Shi et al., 2000). However, the May 2011 survey suggests that there has been significant drop in support in China (from 80+% to 47%) but not in the USA (44% to 46%).

Public acceptance has placed the nuclear issue into a more extensive social and ethic context and represents a great part of public concern of uncertainty about high technology ranging from genetic engineering to nuclear technology. According to the report issued by Energy Advisory Group of the Working Committee on Church and Society in Geneva, the technology-based nuclear energy system is far from being mature and the time for world-wide application of nuclear technology has not arrived yet. Absolute security is a myth, but promising to abolish nuclear technology in the foreseeable future is politically difficult. More public debate and questioning may increase awareness of the opportunities as well as the dangers of the industry, and any anti-nuclear opinions should be discussed.

Thailand

Research on Thai opinions about nuclear energy were made over one month between September and October 2007, conducted by SuanDusit Poll for the Office of Atoms for Peace among 6,117 respondents, representing all parts of Thailand including Bangkok.¹³⁴ There had been general discussion to make a NPP in Thailand since 1977. Nearly one half, 44% of respondents said that they were afraid of nuclear energy, whereas 43 percent did not give an opinion and only 13 percent said they were not afraid of nuclear energy. On the other hand, a question regarding the significance of nuclear energy in developing a country found that 40% saw nuclear energy as very important for a country's development, compared to 35% who saw it as of medium importance and 11% who saw it as very important for a country's development.

The thoughts among respondents about nuclear energy were varied. Most thought that nuclear energy has global utility. Nonetheless, there were some respondents who were aware that the utilization of nuclear energy in Thailand is under the regulation of the Office of Atoms for Peace. Some knew about the generation of electricity by the usage of nuclear energy. Some knew about the utility of nuclear energy in industry, and nuclear energy as an alternative source of medical treatment such as curing cancer, or to extend the shelf-life of food crops and agricultural products. Quite a number of people believed that nuclear energy was not natural.

When talking about nuclear energy 27% of respondents mentioned about nuclear weapons such as nuclear bombs, and missiles, 13% of people said they thought about disaster, destructive explosions and extermination, while 11% thought about nuclear power plants. In the surveys, 31% wished to know more about the benefits and risks of nuclear energy. 15% wished to be informed about the effects on humans, organisms, and the environmental impact by using nuclear energy. Only 12 % wished to know about useful applications of nuclear energy.

Suggestions made by respondents include the following: the public needs to be informed and requires more data focusing on nuclear energy, along with the benefits and risks, secure measurements and protection, and rules and regulations to ensure safe utilization of nuclear energy. The respondents said that they received information about nuclear energy through newspapers and television more than once a month, but not from any other means. Comparing information regarding nuclear energy between 2006 and 2007, 44% of respondents stated that nothing has changed. 28% of respondents sensed that nuclear energy information was increased in 2007 compared to 2006 while 26% of respondents encountered less information on nuclear energy in the same period.

The preferred information source was television, preferred by 27%, 15% would prefer information from newspapers whereas 11% preferred to get information by listening on

134 In the sample, 44% were between 21-30 years old; 45% were graduates with a Bachelor Degree, and 43% had lower than Bachelor Degree, and 8 % had higher than a Bachelor Degree. 27 % were employees of private companies, 26 % were government officials, and 18 % were students. 63% of the respondents were female.

the radio. The most sought-after information about NPPs included the dangers of NPPs, the advantages and disadvantages of NPPs, and radiation protection, respectively.

40% of respondents were uncertain about a need for NPPs, because of insufficient knowledge of the advantages and disadvantages and questions over the competence of regulatory authorities. They wanted public consensus before judging. 31% thought that Thailand was in need of NPPs as an energy option and to ensure stability of economy in the long run. 26% of the respondents were against NPPs. They saw NPPs as dangerous and very harmful to lives and the environment. They thought that NPPs could cause global warming.

The survey asked about the advantages versus disadvantages of NPPs. It found that 30% of respondents were undecided, 26% saw that advantages and disadvantages of NPPs were equivalent, 25% thought there were more disadvantages of NPPs while 13% saw more advantages in NPPs. The respondents were worried about the harm of NPPs in many areas, especially with respect to environmental impact and the effects on lives and the public, respectively.

A post-Fukushima survey was conducted by ABAC Research on NPPs among Thai citizens ranging from 18 to 60 years old who lived within 17 provinces with 3,807 persons, during March 2011. The opinions against nuclear energy have become more negative following the Fukushima accident. 83% of the respondents do not agree to establishing a NPP in Thailand, on the contrary only 17% of the respondents supported the project. In response to the question, "Do you agree to build a nuclear power plants close to where you live?", only 11% agreed while 90% disagreed. Thai citizens were surveyed in all regions of the country. The results clearly show strong disagreement to establishing NPPs in their local areas. 95% of residents who lived in the Bangkok metropolitan area disagreed, followed by 92% of the residents in the South, 90% of the Northern residents, and 86% of the residents in the North East.

Plans to build a NPP in Northeast of Thailand has been postponed since the leakage of radiation in Fukushima, as it is also feared by the locals who have protested about a possible site for a NPP. "The people came because they are afraid about the situation in Japan," said Viroj Jirarungsan, governor of Kalasin Province. Approximately one thousand people gathered protesting the governmental plan to build a NPP.

5.2. Community Engagement on Safety

Nuclear power has been rated with high dread risk in the past few decades (Slovic, 1987; Macer, 1994). Current waste management decisions¹³⁵ are often criticized because they do not incorporate social uncertainties. Current radiation waste risk modelling is based on probabilities of equipment and structural failures, natural disasters, and other physical variables. They often do not consider constantly changing attitudes and ethical opinions, and when they do, it is often subjective. For instance, a detailed study of three different participative decision-making processes employed by France, U.K.

135 For example, cost benefit analysis (CBA), best available technology (BAT), and best available technology not entailing excessive costs (BATNEEC).

and Republic of Korea for their long-term radiation waste management showed that current methods of determining social risk perceptions are predominantly subjective (Rao, 2008).

Ethical principles such as the precautionary principle are often under-utilized when applied to radiation waste management. For instance, in the UK, some of the criteria in formal decision-making models used by the Committee on Radioactive Waste Management (CoRWM) correspond to the precautionary principle, but this was more an *ad hoc* approach (Rao, 2008). The principle is not explicitly acknowledged and modelled into the decision-making process (CoRWM, 2006). In fact, a study of long-term radiation waste management decisions involving geological repositories in the UK, France, and Korea reveal there is no systematic and objective consideration of all the Rio Declaration principles. The study also found that there is inadequate consideration of risk issues, legal principles, and ethical standards. With respect to risk issues, countries did not use objective risk trade-off considerations. With respect to legal principles and ethical standards, key legal principles and ethical standards were discussed on an *ad hoc* basis but not objectively incorporated into their decision-making (Rao, 2008).

The general public often feels that it does not have access to appropriate safety information. For instance, a 2002 joint study of the French nuclear research agency Institut de Radioprotection et de Surete Nucleaire (IRSN) and the Belgian nuclear research agency Studiecentrumvoor Kernenergie (SCK), based on interviews of over 1000 members of the public each in France and Belgium, revealed that more than 60% of the population do not believe that they possess truthful knowledge about nuclear waste risks (Carle et al., 2003). Moreover, while experts can process nuclear information, have access to the latest information, and can ask for the opinions of their colleagues, the general public does not. It may therefore be difficult for the public to grasp the complexity and extremely long timeframes involved in radioactive waste management. To provide an example of the complexity, the US Department of Energy developed a Probabilistic Risk Assessment of the proposed Yucca Mountain repository, which involved 177 variables (Cohen, 2001).

5.3. Nuclear Proliferation

Nuclear energy is intimately linked to nuclear weapons, as the science and engineering for civilian purposes can be adapted for military uses. The issue of such “dual-use technologies” and proliferation is an issue, which is absent in discussions of the ethics of most other energy technologies. For some, nuclear proliferation should be absolutely prohibited. For others, over-reaction to such concerns may conflict with their rights to civilian nuclear energy use.

Using proliferation-resistant nuclear technologies may play a key role in seeking to minimize proliferation risks. Since there is no completely proliferation-resistant fuel cycle or nuclear facility, proliferation resistance is evaluated in relative rather than absolute terms. In nuclear fission, proliferation resistance means getting state actors to stop or reduce uranium enrichment and reprocessing and the spread of these

technologies, and preventing non-state actors from obtaining fuel at any point in the nuclear fuel cycle.

The Nuclear Non-Proliferation Treaty (NPT) guarantees peaceful use of nuclear technology, and enrichment and reprocessing fall under this category.¹³⁶ Moreover, the spread of these technologies, when used for purely civilian purposes, is also allowed under the NPT. Thus, the reduction of these activities and spread of the technology must be built-in to the technology itself, such as the GNEP plans to research, and/or international political pressure must be applied. The use of export controls and IAEA technical verifications are also tools to be used in this regard.

However, traditionally ever since the Atoms for Peace Programme saw unintended consequences of nuclear proliferation, the world is quite wary when it comes to nuclear technology cooperation. There was intense debate between 2008-2009 over the risks and implications of nuclear fuel trade. The recent rhetorical debates on both sides when India, a non-Nuclear Non-Proliferation Treaty (NPT) signatory, signed the 123 agreement with the U.S for peaceful nuclear cooperation, is a case in point.¹³⁷

The costs and benefits of nuclear cooperation are no longer limited to closed-door discussions of scientists or strategic analysts or government bureaucrats. The media, Internet and other social interaction mechanisms lead to rapid formation and influence of public opinion on these issues. However, in the Fukushima case the media could be divided into two groups, one set was those approved to attend the government press briefings as members of Japan Press Club, and the others who were not allowed to join such gatherings. An independent media club was established to allow all journalists to participate in press conferences. Under such pressures, maintaining diplomacy and cooperation without compromising on the ethics of cooperation is an extremely challenging task for both the cooperating governments and the beneficiary governments alike.

The use of export controls and technical verifications here may also reduce any risks of proliferation, chiefly directed at non-state actors such as terrorists. Advancements in proliferation-resistant technologies may also help. While Nunn (2008) and others have proposed steps to curtail nuclear terrorism, such risks and prevention measures as well as technological investments may be costly, and the risk still is non-zero. It may be beneficial to take a more integrated approach to countering this threat. For instance, tactics may need to shift from a predominantly technology and fissile material stock monitoring approach to targeting terror financing and social capital.

The IAEA (2007) has released an advisory on countering nuclear terrorism. Apart from providing an overview of legal instruments, this advisory also includes initiatives of international organizations such as World Customs Organization, Interpol, Europol,

136 See Section 5.5 for detailed discussion of Nuclear Agreements and the NPT.

137 Despite being a non-signatory to the Non-Proliferation Treaty, India has consistently allowed safeguards on its nuclear sites. It has thus far abided to the general procedural conditions by regulations imposing inspections on a regular basis, more specifically safeguards by the IAEA involving six of its fourteen nuclear reactors. Nevertheless it is feared by some that although India will use given fuel for peaceful energy purposes it does leave room for India to use its present domestic fuel sources to further develop further nuclear weapons.

and the Universal Postal Union in countering terrorism. A paradigm shift in terms of how the world community looks at the security of nuclear assets and material, ranging from technological advancements in material detection to raising social capital, may be underway. Governments may benefit from designing a complex fabric of nuclear security on a socio-technical basis. This may involve educating citizens, politicians, and policy-makers to the security implications of nuclear technologies and implementing complex security measures without causing alarm.

The success of proliferation resistant technologies would ease fears over the development of newer nuclear power plants. The availability of existing fission technologies, which are not proliferation resistant, needs to be carefully monitored, if it is not phased out.

5.4. Nuclear International Relations

Theories of international relations explain the way international politics works, but each of the currently prevailing theories is incomplete when taken alone (Snyder, 2004). In particular, none of these theories provide a means to discern proliferation intentions and behaviours of states. This suggests that rather than forcing nuclear driven policies based on a particular approach, policy-makers may benefit from modelling international impacts using multi-disciplinary inputs. According to one defence expert, “[w]hat technologies must we develop to understand and influence nation states...WMD proliferators...the path to understand people, their cultures, motivations, intentions, opinions and perceptions lies in applying interdisciplinary quantitative and computational social science methods from mathematics, statistics, economics, political science, cultural anthropology, sociology, neuroscience, and modelling and simulation” (Popp, 2005). Innovative computer modelling approaches based on complex social computing could be developed that could serve as an ethical platform to objectively evaluate proliferation intentions of states (Rao, 2008).

International Relations experts such as Snyder (2004) suggest three different theoretical approaches - realism, liberalism and constructivism. Realism depicts international affairs as a struggle for power among self-interested states and is generally pessimistic about the prospects for eliminating conflict and war. Refinements of realistic schools of thought include neo-realism and offense defence theory. Theories under the liberalistic approach imply that cooperation was more pervasive but each view offers a different recipe for promoting it. Economic interdependence spread of democracy and creating incentives for cooperation to multilateral agencies such as the IEA and IMF are some of the recipes suggested by the liberalists.

Snyder (2004) suggests that constructivist approaches emphasize the impact of ideas upon society. The common theme of constructionist strands is the capacity of societal discourse to shape how political actors define themselves and their interests, and thus modify their behaviour. Constructivists believe that international politics is shaped by persuasive ideas, collective values, culture and social identities. The destructive power of nuclear technologies has an uncanny ability to affect all the three theories in a complex manner and still pose difficult questions for world peace.

Nuclear technology cooperation between developed and developing countries exists in various fields, most notably technology transfer and funding. Such cooperation, however, come with proliferation concerns. Collective approaches such as the GNEP (Global Nuclear Energy Partnership) were purportedly designed for peaceful purposes while simultaneously minimizing the attendant risks. Through GNEP, the United States will work with other nations possessing advanced nuclear technologies to develop new proliferation-resistant recycling technologies in order to produce more energy, reduce waste and minimize proliferation risks. Partner nations will develop a fuel services program to provide nuclear fuel to states not possessing enrichment and reprocessing capabilities, which tend to be mostly developing countries, allowing them access to sources of nuclear energy in a cost effective manner in exchange for their commitment to forgo enrichment and reprocessing activities (Department of Energy, 2006). However, the envisaged mechanism of establishing a group of fuel supplier states raises ethical questions of selective technology sharing and dominance that discriminate between states. As the fuel recipient states tend to be mostly developing countries, a further ethical dilemma is raised: whether nuclear energy cooperation really provides enhanced energy security for developing states or merely shifts their dependencies from fossil fuel countries to nuclear fuel countries.

Dependency of developing countries on the developed countries for nuclear fuel, funding, and nuclear commerce inevitably influences recipient states. In the event of increased use of nuclear energy, in particular as envisaged in developing countries such as India and in the simultaneous event of denial of reprocessing technology transfers and rights under regimes such as GNEP, the issue of how to deal with spent fuel would create regional concerns with complex geopolitical issues. Such developments should perhaps be monitored and an environment for free and positive relations among states be fostered.

Empirical findings by Asal and Beardsley (2007) using international crisis behaviour datasets have suggested that while the probability of a full-scale war declines sharply if the number of nuclear powers involved in a crisis increases, it still does not rule out minor clashes. Probability of serious clashes is more or less immune to the number of nuclear actors involved in the crisis. Consequently an important observation for policy makers is that while the role of credible nuclear deterrents can probably avert full-scale wars, it still cannot assure peace since minor and serious clashes are still likely to continue. Hence it becomes necessary to look at de-escalation mechanisms in tandem with deterrence mechanisms. This marks another key complex attribute of nuclear technologies wherein non-nuclear mechanisms surround the nuclear issue, making ethics based policy action interventions quite challenging.

The advent of the atomic bomb has changed the face of international relations conclusively. While nuclear-influenced foreign policies are inevitable, sufficient checks and balances need to be institutionalized by organizations such as the U.N. in order to avoid run-away reactions of nation states to nuclear challenges.

5.5 Nuclear Agreements

5.5.1 Scope and Evolution

The governing regime that regulate the development and use of nuclear technology, nuclear materials and related equipments, their export and trade, whether for nuclear power or non-power application, and the prevention from the diversion of nuclear energy from peaceful uses to nuclear weapons or other nuclear explosive devices, consists of numerous bilateral, regional and multilateral agreements. Predominated by safety and security related norms, there are 166 comprehensive safeguards agreements¹³⁸ and 140 additional protocols,¹³⁹ this regulatory mechanism together with a highly institutionalized,¹⁴⁰ quasi jurisdictional system of safeguards and verification under the national and international monitoring, constitute a complex structure of specialized legal and institutional framework - nuclear law. Defined as “the body of special legal norms created to regulate the conduct of legal or natural persons engaged in activities related to fissionable materials, ionizing radiation and exposure to natural sources of radiation” (Stoiber et al., 2003), nuclear law is well established domain in public international law. By contrast to this ‘broader’ definition, to highlight at this point, other sources, more traditionally refer to it as a non-proliferation regime. On this ground, for example, it is classified into: i) bilateral treaties between the two former superpowers, the USA and the USSR, ii) regional treaties on nuclear weapon free zones and, iii) multilateral global agreements on non proliferation and peaceful use of nuclear technology (Bassiouni, 2000). Legal and ethical implications of these two approaches are discussed in the “Non-proliferation: safeguards and nuclear export control” section below.

Apart from disarmament and non-proliferation regimes, the Office of Legal Affairs of IAEA, European Atomic Energy Community, Nuclear Law Committee of OECD/NEA and International Nuclear Law Association are amongst the key contributors in the advancement and harmonization of international nuclear law, in a substantive part, the development of nuclear science and technology, nuclear liability and compensation regimes with due contribution of the USA, German and French national legislations as standard setters. The evolution of nuclear law and its scope of coverage correspond to the general tendency observed in the development of public international law; that is, the expansion and specialization of rules, characterized as,

“... fragmentation of the international social world has attained legal significance especially as it has been accompanied by the emergence of specialized and relatively

138 The Final Document of the 2010 Review Conference of the Parties to the *Treaty on the Non-Proliferation of Nuclear Weapons*. New York 2010. Volume I, Part I, paragraph 14.

139 2010. Status of Additional Protocols International Atomic Energy Agency. http://www.iaea.org/OurWork/SV/Safeguards/sg_protocol.html

140 This section is devoted to legal regulations. For historic evolution and the current state of institutional framework, including: IAEA, The Zangger Committee, Nuclear Suppliers Group and OECD, see 2010. *International Nuclear Law: History, Evolution and Outlook*. OECD NEA No.6934, pp.13-91. Also, *MCIS CNS NPT Briefing Book 2010 Annex Edition*, Part II, Sections H and M. For the role and status of Ten-Nation Disarmament Committee and Eighteen-Nation Committee on Disarmament, see also UN General Assembly Official Records: Tenth Special Session, Supplement No. 2 (A/S-10/2)

autonomous rules or rule-complexes, legal institutions and spheres of legal practice. What once appeared to be governed by "general international law" has become the field of operation for such specialist systems as "trade law", "human rights law", "environmental law", "law of the sea", "European law"..."(UNILC, 2006).¹⁴¹

In a relatively short period of time from its original intention to prohibit nuclear disarmament and non-proliferation, dating back to the 1950s, it has been expanded to address management of radiological crisis, management of radioactive waste and sources, transportation and storage of nuclear and radioactive materials, physical protection of nuclear facilities including from terrorist attack, nuclear installation and decommissioning, and liabilities from nuclear damage and compensation. In other words, this expansion aimed to "... encompass all aspects of the use of radioactivity" (Leger, 2007).

Diversification of nuclear law is another attribute of its evolution. Based on objectives and substantive content of norms, and principles applied, development of this legal domain can be grouped into the following (relatively) distinct clusters of specialization: i) non-proliferation regime, ii) the liability and compensation for nuclear damage, iii) safety, radiological protection and emergency response, iv) spent nuclear fuel and radioactive waste management. These areas of functional specialization, with exception for liability and compensation regime, also correspond with their chronological order. Whereas, the liability for nuclear damage significantly preceded the compensation and dated back to the 1960s when Paris Convention on Third party Liability in the Field of Nuclear Energy (1960) and Vienna Convention on Civil Liability for Nuclear damage (1963) were adopted. The Chernobyl accident in 1986 and the terrorist attack on 11 September 2001 in the USA had "...brought to light the limitations and deficiencies of the legal regimes in place, both in terms of preventing nuclear accidents and in terms of compensating victims thereof in the event of their occurrence... [T]he insurance cover of damage resulting from a nuclear accident caused by a terrorist attack." (Julia, 2007).

Before the closer analysis of these clusters, a few remarks on equally important and growing spheres of nuclear affairs, namely: transport of nuclear and radioactive materials, environmental protection related to nuclear activities, scientific, commercial and industrial application, and nuclear trade and export. Yet none of them evolved to such a level to constitute a rule-specific cluster as they are ruled out by safety-liability and security-non-proliferation regimes.

In transport of nuclear and radioactive materials a mode of transportation of little significance for nuclear law (technical norms are not referred)¹⁴² but the classification and quantity of nuclear/radioactive material. To take an example, for the protection of transporting material - the Convention on the Physical Protection of Nuclear Material, 1980; transportation of nuclear waste - the Joint Convention on the Safety of Spent Fuel

141 Report of the Study Group of the International Law Commission, *Fragmentation of International Law: Difficulties arising from the diversification and expansion of international law*. 2006. A/CN.4/L.682

142 IAEA. 2005. Regulations for the Safe Transport of Radioactive Material. 2005 Edition. Safety Requirements No.TS-R-1. Specific mode and route of transportation governed by international customary law and international law on transportation and navigation.

Management and on the Safety of Radioactive Waste Management, 1997; accident in course of transportation - the Convention on Early Notification of a Nuclear Accident, 1986; emergency response for accident - the Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency, 1987.

Notwithstanding the fact that development of nuclear law had preceded the modern environmental law, we refer to the Stockholm Conference on the Human Environment (1972) and emergence of the 'first generation' of environmental laws, yet common approach among the nuclear lawyers is that nuclear activities should be the subject of environmental law and governed by its principles, rather to establish specific rules driven by this 'technical' law. In fact, number of environmental principles recognized and incorporated into the nuclear law under the rules-complexes for safety - waste management as a preventive measures, and damage - liability related instruments for emergency response and effective mitigation of caused damages. Nevertheless, "...the dominance of the traditional anthropocentric approach of nuclear law, which focuses on protecting people and property instead of the environment..." rooted back to its origin, "... to guide and regulate the development of nuclear activities for civil use." (Emmerechts, 2010, p.122; Sam, 2010).

Trade and export of nuclear technologies and related materials, and scientific cooperation - nuclear energy for electricity production, is likely to form an independent cluster of rules. Among the driving factors, a growing investment from the private sector in parallel with strengthening environmental standards require a stronger tie with the financial sector of insurers. Provided that current "minimum competition rules" (Michel, 2010, p. 275) apply and the global nuclear power market is liberalized, then a major challenge for nuclear law is to articulate its prohibitory and regulatory measures with an account to balance legitimate interests of environment, society and a development of nuclear industry. An ethical issue is how to prioritize these interests.

Despite this wide area of cross-sectoral and multi level application, norms and rules of nuclear law remains interdependent. Dictated by the nature of the risks associated to the use of nuclear and radioactive materials, this strong interdependence is only observed in environmental law (Leger, 2007). This interdependence secured by fundamental concepts of nuclear law: security, safety, and safeguards. So-called 'Three-S' concept, it reflects the key "... *technical* [emphasize is added] areas which need to be addressed in establishing an adequate legislative and regulatory framework." (Stoiber et al., 2010, p.4).¹⁴³ Hence no total illumination of potential risks and associated damages, nuclear liability (supplemented by compensation) is regarded to be one of the fundamental concepts of nuclear law, in addition to the 'Three-S'.

143 Stoiber, C. et al. 2010. *Handbook on Nuclear Law: Implementing Legislation*. International Atomic Energy Agency, Vienna. Other sources suggests relatively longer list of fundamental concepts, namely: *security, safety, responsibility, permission, continuous control, compensation, sustainable development, compliance, independence, transparency and international cooperation*. Many of these concepts, few of them in fact state the operational environmental rather than fundamental concept, are not specific to nuclear sector but equally shared by other sectors.

5.5.2. Safeguards and nuclear export control

In the course of long lasting negotiations between the USSR and USA from 1955 to 1963 on arms control and disarmament, which was temporarily suspended in 1960 due to the first French nuclear test and limited to exchanges of views, the three nuclear-weapon States held that agreement on non-proliferation should not be dependent on the implementation of other disarmament measures. Giving the urgency and higher importance on preventing the proliferation of nuclear weapons, UN by its Resolution 2028 (XX) from 1965 called the Conference of the Eighteen-Nation Committee on Disarmament - a broker between the USSR and USA, for urgent consideration of the question of non-proliferation of nuclear weapons and to negotiate international treaty. In three years, draft text of the Treaty on the Non-proliferation of Nuclear Weapons was ready for voting; and after this occasion of voting by 95 countries were in favour, 4 against with 21 abstentions, the Treaty became open for signature and entered into force in 1970. In addition to the Limited Test Ban Treaty (1963),¹⁴⁴ it was another significant step to further the goals of general and complete disarmament and, more particularly, nuclear disarmament at the global level. In 1995, at the Review and Extension Conference, the duration of the Treaty was extended indefinitely by a consensus decision and with 190 states as the parties to the Treaty (as of June 2010)¹⁴⁵ it had become the most widely accepted arms control treaty.

The Treaty does distinguish nuclear weapon states (NWS) and non-nuclear weapon states (NNWS)¹⁴⁶ as it was mandated by UN and laid out in its Resolution 2028 (XX) through the list of five principles that had have served as the basics at the time of NPT negotiation. One of these principles stipulated that “the treaty should embody an acceptable balance of mutual responsibilities and obligations of the nuclear and non-nuclear Powers”¹⁴⁷ and embodied into the Articles I and VI of NPT, accordingly, NWS obliged not to transfer nuclear weapons or explosive devices and to pursue “... negotiations in good faith on effective measures relating to cessation of the nuclear arms race at an early date and to nuclear disarmament...” With regard to NNWS, the Article II of the Treaty imposed them not to receive, transfer or manufacture nuclear weapons and other explosive devices. Furthermore, in compliance with the paragraph 1 of the Article III, the NNWS must accept the *full scope safeguards* to allow international and unilateral (the country of origin) inspection “... on all source or special fissionable material in all peaceful nuclear activities within the territory of such State, under its jurisdiction, or carried out under its control anywhere.” Articles IV and VII of the Treaty contains other substantial elements, accordingly, the right to conclude nuclear

144 Full formal title refers as Treaty Banning Nuclear Weapons Tests in the Atmosphere, in Outer Space, and Under Water, 1963.

145 The Final Document of the 2010 Review Conference of the Parties to the Treaty on the Non-Proliferation of Nuclear Weapons. NPT/CONF.2010/50 (Vol. I). New York, 2010.

146 As defined by NPT, this is a state which has not manufactured and exploded a nuclear weapon or other nuclear explosive device prior to 1 January 1967. Whereas, NNWS are any state that manufactured and exploded a nuclear weapon or other nuclear explosive device prior to 1 January 1967. Including, the Russian Federation (as successor state to the Soviet Union), the United States, the United Kingdom, China and France. Therefore, by NPT definition India, Israel and Pakistan, are not a nuclear-weapon state under the NPT definition See MCIS CNS NPT Briefing Book, 2010 Annecy Edition. p.25 on Abbreviations, Acronyms and Glossary of Terms.

147 UN General Assembly, Resolution 2028 (XX), the 1382nd plenary meeting, 19 November 1965.

weapon free zone, though no security assurance from NWS and acknowledgement of “the inalienable right” for the peaceful uses of nuclear energy.

The two approaches to nuclear law highlighted earlier in “Nuclear law: overview” section of this report, have different emphasizes when to define and weight the status of the core elements, chiefly in a view of their interrelation. The most fundamental distinction, that is, equity in status and significance amongst the core elements of NPT as opposed to the solo supremacy of non-proliferation, had its origin from contesting views on value superiority between *partialmeasures* – non-proliferation of nuclear weapons and ban of a nuclear test, and *comprehensive measures* to pursue complete and general disarmament including nuclear weapons.

From the perspective of military doctrine and policy debate, these two approaches do reflect two contrary positions on general disarmament; on the one hand, it is argued that arms races will be in lead to a tension and war. The opposing view suggests that military spending is just a reflection of existing insecurities and conflicts, which have to be settled first. From the latter perspective, while some military strategists continue to support arsenals with more destructive power to help achieve their objectives, there is increasingly less support for the possession and threat of use of nuclear weapons (Advisory Opinion, 1996). As an example, the bilateral agreements between the United States and USSR, now Russia, have led to actual reduction of nuclear weapons and associated technology. The Treaty between the USA and the USSR on the limitation of anti-ballistic missile systems (ABM Treaty), 1972, on the limitation of strategic offensive arms (1979), on the elimination of their intermediate-range and short-range missiles (1988), the limitation of their underground nuclear weapons tests (1990) have brought about notable reductions in both the countries belligerent nuclear capability. With the expiry of an earlier Treaty on strategic offensive arms reduction (2002), a fresh treaty has been signed in April 2010 by Russia and the United States pledging further reductions (START II, 2010).

5.5.3. The “three pillars” as the core elements

The NPT key elements that embodied in the Articles I and III for NWS, along with the Articles II and IV, that primarily concerned to NNWS, have come to be described as ‘three pillars’ of the Treaty – non-proliferation, disarmament and peaceful use (Kuppuswamy, 2006). This concept ascribes that the three elements constituting the central structure of NPT are equal in significance and therefore, a balance among these three components must be maintained. Proponents of this position include NWS and NNWS; however, objections related to the operational environment of safeguards and export control rules are divisive issues between the NWS plus NNWS exporters as opposed to the NNWS recipients.

A substantial part of the dispute focused on a procedural matter. On the ground of lack of transparency it is argued that safeguards and export control rules are discriminatory towards the nuclear recipients; and they impose unjustified burden and barriers, and thereby, hindering one of the core elements of NPT - the peaceful use of nuclear energy. It is fact that number of rules on safeguards and export control has been discussed outside of UN, and the NPT governing forum - the Review Conference and IAEA, but

through the 'Zangger Committee' and 'London Club' or the Nuclear Suppliers Group. These are informal groups,¹⁴⁸ which have no status in international law. The Zangger Committee was set to reach a common understanding among the nuclear exporters on the terms of the Article III.2 of NPT: "(a) source or special fissionable material" and "(b) equipment or material especially designed or prepared for the processing, use or production of special fissionable material." Perhaps it is natural that those who possess know-how on nuclear technology are technically in a relevant position to define it, so did the Zangger Committee; who unilaterally had set the conditions for nuclear export through enlisting nuclear equipments and materials, based on its 'understanding' of thereof, on a 'Trigger List' which meant to trigger safeguards requirements in case of their export. The outcome of its decision communicated to IAEA Director in a form of a letter along with a request to inform IAEA Member States about the decision.¹⁴⁹

The Conference of Parties to NPT, on the other hand, through a series of recommendations adopted at its Review Conferences, while acknowledging the Zangger Committee's contribution on non-proliferation of the nuclear weapons, has requested for a dialogue with NPT State Parties and underlined that balance between the core elements of NPT should be maintained. For example, at the Fourth NPT Review Conference in 1990, it was stressed that:

"... the Conference requests that the Zangger Committee should continue to take appropriate measures to ensure that the export requirements laid down by it do not hamper the acquisition of such items by states parties for the development of nuclear energy for peaceful uses."¹⁵⁰

Another recommendation from the NPT Review and Extension Conference, 1995, stated that:

"The Conference notes that the application by all States of the understandings of the Zangger Committee would contribute to the strengthening of the non-proliferation regime. The Conference calls for *wider participation in international consultations among all interested States parties concerning the formulation and review of such guidelines* [emphasize is added], which relate to the implementation of States parties obligations under article III, paragraph 2."¹⁵¹

148 With 37 Members as of the year 2010 including all NWS, the Committee, named after its first Chairman Prof. Claude Zangger, was formed following the coming into force of the Nuclear Non-Proliferation Treaty (NPT), to serve as the "faithful interpreter" of its Article III, paragraph 2, to harmonize the interpretation of nuclear export control policies for NPT Parties. Source: <http://www.zanggercommittee.org/Seiten/default.aspx>

149 For example, Annex to INFCIRC/209/Rev.1 from 1990 on Zangger Committee's decision *Regarding the Export of Nuclear Material and of Certain Categories of Equipment and other Material*: "I have the honour to refer to [relevant previous communication in which the Government of [Member State] informed you that it had decided to act in accordance with certain procedures in relation to exports of nuclear material and certain categories of equipment and other material which you circulated to all Member States of the Agency as document INFCIRC/209, and to [relevant subsequent communications] informing you of its desire to clarify certain items described in the Annex "Clarification of Items on the Trigger List" to Memorandum B and circulated as documents INFCIRC/209/Mods.1,2,3 and 4. [...] I should be grateful if you would circulate the text of this letter and its attachment, together with the appended background paper, to all Member States for their information.

150 NPT/CONF.IV/DC/1/Add.3 (a), p. 5, paragraph 27

151 INFCIRC/482, attachment, paragraphs 5 and 7.

As a response to the critics on lack of transparency, the Zangger Committee has launched an Outreach Programme between the Committee and the nuclear recipient countries, 2001. One of the objectives of this Programme is “to provide opportunities for open dialogue on issues of common interest and concern on non-proliferation and nuclear export controls,” yet underlining that “the outreach programme reflects the fact that the Zangger Committee is a technical body with a remit to interpret article III.2 of the NPT and as such outreach will not be a political dialogue”.¹⁵² Furthermore, the Committee has prepared a Working Paper on Multilateral Nuclear Supply Principles of the Zangger Committee, in 2000 and 2005; wherein, its role has been seen to “... essentially contributes to the interpretation of article III, paragraph 2, of the Treaty and thereby offers guidance to all parties to the Treaty”, which in turn “... helps to prevent the diversion of exported nuclear material and equipment or material from peaceful purposes to nuclear weapons or other nuclear explosive devices, [thereby] furthers the objectives of the Treaty and enhances the security of all States.”¹⁵³

The Nuclear Suppliers Group (NSG), a nuclear exporting countries set up in 1975, put forward two sets of guidelines for nuclear transfers and for nuclear related dual-use items and technology: the first set of guidelines, governs those items that are especially designed or prepared for nuclear use while the second, for dual-use items and technologies - missing elements in NPT. Compared to the Zangger Committee, the NSG has broader objectives (INFCIRC/539);¹⁵⁴ not restricted with the Article III.2 of the NPT, that is nuclear equipment and material, the NSG also does meant to regulate the technology and know-how, termed as *sensitive facilities, technology and weapons-usable materials*,¹⁵⁵ in addition to the dual use items. Like in case of the Zangger Committee, concerns on discriminatory approaches over the safeguards transparency and nuclear trade, inclusiveness and open dialogue remains one of the main demands of a large number of NNWS – nuclear recipient states in particular; and was called for by the NPT Review and Extension Conference (1995) and embodied in the final document on “Principles and Objectives.”

These procedural ‘barriers’ have had an effect on substantive matters as well. The NSG’s strengthened rules originated from a proliferation concern; as they were introduced to counter noncompliance states, but also to counter with the ‘free-riders’ on the system; those, who did share the benefits of a global and regional security derived from non-proliferation regime, while remains free from any commitments and responsibilities; unlike the NPT state parties, whose “inalienable right” for the peaceful uses of nuclear energy which is recognized under the NPT had become the subject of a tighter control and regulations. These stringent requirements on safeguards and export control include the principle of universality - the full scope safeguards agreement with IAEA is a condition to transfer nuclear materials, whether the recipient country is the NWS,

152 Zangger Committee, Outreach Programme. Source: <http://www.zanggercommittee.org/Outreach/Seiten/default.aspx>

153 Multilateral nuclear supply principles of the Zangger Committee. New York, 2-27 May 2005. NPT/CONF.2005/WP.15. Source: <http://www.zanggercommittee.org/Documents/NPTWP152006.pdf>

154 The Nuclear Suppliers Group: Its Origins, Roles and Activities, INFCIRC/539 from 1995.

155 Guidelines for Transfers of Nuclear-Related Dual-Use Equipment, Materials, Software and Related Technology. INFCIRC/254

NNWS or non party to the Treaty;

Dual-use regime - a list of nuclear related dual-use equipment, materials, software and related technology that can be used for nuclear and non-nuclear purposes. This List supplements the Trigger List;

'Catch-all' clause - any nuclear items, materials and related technologies not included in Trigger and Dual-Use lists, but with a potential to be used for proliferation are under the subject of authorization;

Non-proliferation principle - when there is an unacceptable risk of diversion and/or when there is an unacceptable risk of diversion to acts of nuclear terrorism, no authorization to transfer of dual-use nuclear material, equipment, software and related technology; notwithstanding the safeguards agreement with IAEA and the recipient government's assurances of peaceful use and physical protection measures.

Rules under the items ii), iii) and iv) implies that existing safeguards mechanism – full scope safeguards, which is based on *declared* information and data related to imported (and exported) items is not sufficient, but to widen it to *undeclared* or in-country inspectorate. While item iv) shifts the burden of proof from international regime - IAEA assurance, into the judgment of nuclear suppliers. This received as interference with sovereignty, in a manner that "...manifestly contradicted one of the fundamental principles of the NPT which granted NNWS the right to develop research, production and use of nuclear energy for peaceful purposes;" (Michel, 2010, p. 275) and "... the intention of industrialized countries to continue their monopoly" over the nuclear know-how based on a "minimum competition rule" (Michel, 2010, p. 275), while for others, as a tool of industrial espionage by advanced nuclear states.¹⁵⁶ Contrary, NSG rules on export control characterized as "... they have no single orientation;¹⁵⁷ in a sense that NSG is neither trade promoter or to restrict it, and that is, an implied adherence to non-proliferation. While others more explicit, suggesting that NSG with its new export regulations apparently changing existing balance between non-proliferation and peaceful use, and replacing it by priority rankings (Michel, 2010).

5.5.4. The original intent as the core element

In contrast to the *three pillars* concept, it is argued that "... the language pointing to the three pillars as essential and equal components of the non-proliferation is not just misleading - it poses a danger to the security of those nations [...]. The other two elements [disarmament and the peaceful use] of the treaty are not really pillars at all; they are subordinate clauses under the central purpose of nuclear non-proliferation" (Spring, 2010). Proponents of this concept mainly rely on original intent method when interpret the NPT, that is an attempt to ascertain what the negotiators meant when they agreed on NPT, and on historic documents. On this ground, especially in attempt to frame 'the original intent', it is said that it was the most ambitious attempt ever

156 Mark Hibbs, *Nuclear Suppliers Group and the IAEA Additional Protocol*. Nuclear Energy Brief, 18 August 2010.

157 Carlton E. Thorne, former Chair of NSG Working Group. *Multilateral Nuclear export Controls: Past, Present and Future* - keynote speech at the International Seminar on The Role of Export Controls in Nuclear Nonproliferation. 1997, Vienna, Austria.

made by the nuclear weapon states in their efforts to constrain the acquisition and use of nuclear weapons (Perkovich, 2006). In this regard, we can recall the remarks of the late U.S. President John F. Kennedy's interview from March 1963, who said: "[...] I am haunted by the feeling that by 1970 [...] there may be 10 nuclear powers instead of 4 and by 1975, 15 or 20 [...] I would regard that as the greatest possible danger and hazard" (Graham, 2010), amongst the popular quotations in computing the 'original intention'.

In the same spirit, one of the principles laid down in the UN Resolution 2028 "the treaty should embody an acceptable balance of mutual responsibilities and obligations of the nuclear and non-nuclear powers" is claimed to be the central bargain of NPT (Graham, 1996; Graham, 2010). This balance of responsibilities and obligations has been seen as a strategic arrangement founded on a 'central or grand bargain': wherein, nuclear energy for peace was made available in *exchange* for nonnuclear weapon state's commitment not to obtain and manufacture the nuclear weapons. The nuclear weapons states, *in return*, pursue nuclear disarmament to grant the participation of NNWS, industrialized countries in particular. (Graham, 1996; Graham, 2010; Miller and Scheiman, 2002 – emphasis in *italics* is added).¹⁵⁸

The NPT is a framework agreement: a flexible instrument to accommodate an evolving security environment and to timely address new proliferation threats as an outcome of advancement in nuclear technology, for example, NPT does not address nuclear technology but equipment and material, this and other gaps were addressed without amending the text of the Treaty; arguments on 'bargain' are not credible from a legal perspective. In this regard, and at the first level argument, derived from the framework nature of the Treaty; examination of the operation of the Treaty takes place every five years during the NPT Review Conference, suggesting that NPT is legally open for interpretation by its 190 signatory state parties rather to attempt to 'reveal' the original intent or its dominance. Otherwise, and the second argument, a validity of NPT from a perspective of its source could be questioned. Indeed, despite the fact that general and complete disarmament was co-sponsored by all UN Members and was mandated by UN General Assembly Resolution 2028. Importantly, a significant part of the NPT negotiation process went outside of the UN system through the Eighteen-Nation Committee on Disarmament - a negotiating body of restricted membership, which had composed exclusively of representatives that agreed by USSR and USA.¹⁵⁹

Other grounds of the critique of 'the original intention' point towards horizontal proliferation, whereas the NPT, is more or less but a reflection of misleading notion of those few states who had have a know-how in building the nuclear weapons and prohibition of a vertical proliferation seem to be achieved. It is natural that 'the original intention' had been accused for it's sought to preserve the status quo, in other words, a legalization of military and technological advances, and a post-ratification division into

158 Marvin Miller and Lawrence Scheinman. 2003. Israel, India, and Pakistan: Engaging the Non-NPT States in the Nonproliferation Regime. *Arms Control Today*, December.

159 Special Report of the Conference of the Committee on Disarmament, Volume I, pp. 2-5. General Assembly, Official Records: Tenth Special Session, Supplement No. 2 (A/S-10/2), United Nations.

the 'haves' and the 'have-nots'.¹⁶⁰ As earlier as in 1965, eight members of the Eighteen-Nation Committee on Disarmament¹⁶¹ had emphasized that non-proliferation, as a partial measure, should run in parallel with comprehensive measures in order to achieve the goals of general and complete disarmament of nuclear weapons. These two contesting positions on value priorities, *partial* and *comprehensive* measures, put in query existing international customary and humanitarian law practices and principles.

5.6. Justice and Equity

One of the particular issues of nuclear energy technology ethics concerns equity and justice issues. Developing countries are spending considerable sums on nuclear energy. When a significant proportion of the population suffers from the lack of basic needs this may represent an injustice to the poor and the marginalized of a given society. However the fact that 1.4 billion people lack access to electricity (ADB, 2008) runs contrary to the principle of justice.

Aside from the human health and environmental effects of uranium mining, there are also equity issues in how these risks are spread among the population. Although many formulations of equity exist, one divides intragenerational equity from intergenerational equity (see for example, Okrent, 1999). Intergenerational equity, a concept popularized by the Brundtland Commission Report (WCED, 1987), can be formulated as being equivalent "to the rejection of a 'time preference' that would allow the living to take advantage of their position and strength" (Agius, 2006) over future generations. If uranium mines are not remediated, a cost is imposed on future generations. If nuclear waste sites are insecure for a long period, the radioation will leak affecting the health of future generations. In terms of intragenerational equity, which is similar to the concept of economic equity, it may not be fair or just for those who benefitted from nuclear power, who are in one part of the world (e.g. certain parts of the US, Japan, and France) and who benefit from the relatively clean generation of nuclear power, to be exempt from the relatively dirty, and sometimes dangerous, effects of uranium mining, and waste disposal.

Equity in sharing risks and benefits is a problem, which is shared with other power sources. For instance, wind turbines (in wind power) are generated on land close to those who must endure the noise and obstruction to their visual scenery. Many people are displaced by dams. However, the effects are particularly acute for uranium mining due to radiological effects. A counter consideration, however, is that mining villages and towns may benefit economically from mining activities. Many people are displaced due to construction of dams, loss of agricultural land is yet another negative externality. However, the effects are particularly acute for uranium mining due to radiological effects. A consolation argument is that though mining villages and towns may benefit economically from mining activities, the eventual contamination of arable

160 During the Cold War, as an example, International Industrial list was designed to impose trade and export restrictions on non-proliferation uses of nuclear materials and related equipments. *Encyclopedia of Business*, 2nd ed.

161 *Ibid.*, p. 8 paragraph 26.

land and other natural water bodies that are still the major subsistence sources for the local people is inevitable.

Equity issues are also important with respect to nuclear weapons spending. Renner (2007) notes that the number of nuclear warheads held in 2006 by five of the world's nuclear powers— the United States, Russia, the United Kingdom, France, and China— was estimated at about 27,000, down from a peak of about 70,000 in 1986. The US and Russian nuclear stockpiles account for over 97% of the warheads. Renner also provides estimates that around 2500 nuclear warheads remain on high alert status. Examples of costs of maintaining nuclear weapons are given below:

The 1972 Strategic Arms Limitation Treaty I (SALT I) led to a sharp curtailment of any further anti-ballistic missile (ABM) development efforts. In 1974, a treaty revision allowed the U.S and the Soviet Union to retain only one ABM site each. The American site became operational in 1975 but Congress ordered its termination within four months. Before site shutdown, the cost was 21.3 billion USD (Garrison, 2006).

The total incurred costs of the U.S. nuclear weapons program exceed 5.8 trillion USD in the period between 1940 and 1996. This includes 320 billion USD in estimated future-year costs for storing and disposing of more than five decades' worth of accumulated toxic and radioactive wastes, and 20 billion USD for dismantling nuclear weapons systems and disposing of surplus nuclear materials (Schwartz, 2008).

The average French nuclear defense budget per annum for 2003-2008 was planned to be 3.8 billion USD. For comparison purposes, the defense budget for 2006 was 49 billion USD (Tertrais, 2007).

Comparing nuclear defense spending and budgets with country's budgets for education and development reveals that military intentions are often higher (GPF, 2009). The ethics of distributing societal financial resources for nuclear military expenditure versus developmental expenditure is a perpetual question in national governance. The governments involved, which are for the most part developed economies, may consider the opportunity cost to the impoverished when considering such spending.

An analysis of the data shown in paragraph 1.3 reveals that some developing countries are spending a greater proportion of their national income on nuclear energy compared to the proportion of GNP spent by developed countries. For example in India, more than half of the population lives below the poverty line, and there have been many suicides by farmers in 2008 due to an inability to grow enough food (Lohan, 2009). While the investment costs of generating energy from a NPP can be higher than the thermal or hydroelectric methods of power generation, the justice principle would likely dictate that the relative cost of energy, whether nuclear or not, should be comparatively less, rather than more, in comparison to developed countries. To meet this ethical obligation of justice, developed countries may provide funding and development assistance or technology transfers and cooperation with developing countries.

Since its independence, the issue of poverty within India has remained a prevalent concern. According to the common definition of poverty, when a person is unable to meet the minimum requirement of acceptable living standards, he or she is considered

to be living in poverty. For example in India, millions of people are unable to meet the basic standard of living. According to Indian government estimates, in 2007 there were nearly 220.1 million people living in poverty. Poverty, in India or elsewhere, has dire downstream effects.¹⁶² If the cost of nuclear energy is relatively more for countries with high poverty rates, there will be less funding available to be spent on education, basic health and living.

Thus, in this further application of the justice principle, justice is *relative* for each country because it depends on the wealth of the given country. For example, nuclear technology development in India may not be justified if basic amenities of the people are not fulfilled. Basic amenities represent high value per dollar of investment, and if such money funds nuclear technology development, a large opportunity cost is imposed. However, in the case of developed countries such as France, nuclear technology development is more justifiable because basic amenities of a large proportion of the population are met.

5.7. The Right to Development

While the right to sustainable energy arguably deserves to be recognized as a fundamental human right, the current status on a generalized basis is that this right exists not as a substantive right by law/constitution but rather as procedural right (Wilson and Anderson 2005). However, a substantive emphasis is required to set objectives for energy policies and programmes.

Given the complexity of the technology, it then becomes necessary to examine the imperatives of international/national policies and treaties/programmes on nuclear energy in light of a human rights based approach. The United Nations Development Group (UNDG) Resolution adopted in 2003, stated,

"International policies and treaties on nuclear technologies need to take cognizance of the human rights principles of universality and inalienability; indivisibility; interdependence and inter-relatedness; non-discrimination and equality; participation and inclusion; accountability and the rule of law."

A case for a right to a particular energy source such as nuclear energy remains ambiguous. For instance, while Article IV of the NPT states that signatories have a substantive and "inalienable right" to peaceful use of nuclear energy, it is subject to conditions. While this can be easily justified as a sovereign right, distributing this right down to the population can only, if at all, be achieved through relying on a human rights framework. Human rights are guaranteed by the sovereign to its people, in the interaction between the two. It is in this context that the UNDG Resolution of 2003 comes to life. State policy on nuclear energy should (presuming this right falls within the categorisation of economic, social and cultural rights) be progressively

¹⁶² The World Bank, 2009

<http://web.worldbank.org/WBSITE/EXTERNAL/EXTABOUTUS/ORGANIZATION/BODEXT/0,,pagePK:64020055~theSitePK:278036,00.html>

set to achieve full and affordable provision of sustainable energy for all, without discrimination. Unless understood in this way, the application of procedural rights to nuclear energy in particular is ambiguous. For example, the United Nations Framework on Climate Change (UNFCCC) excludes nuclear technologies in two of the three flexibility mechanisms under the Kyoto Protocol related to Annex I Parties as discussed in section 6.3.

Given the complexity of applying the term “rights” to nuclear energy, it may be useful to examine the imperatives of policies, treaties, and programmes on nuclear energy in light of a human rights based approach, which can be found among the countless documents and understandings produced.

As an example which shows the human rights based approach at work, the outcome of the Interagency Workshop on a Human Rights based Approach in the context of UN reform 3-5 May 2003 might be used. A common understanding was reached at the workshop entitled, “The Human Rights Based Approach (HRBA) to Development Cooperation towards a Common Understanding among UN Agencies” (HRBA, 2003). It outlined various principles to be followed in all phases of programming, including: universality and inalienability, indivisibility, interdependence and inter-relatedness, non-discrimination and equality, participation and inclusion, accountability, and the rule of law.

Further, UN High Commission on Human Rights (UNHCHR) guidance (UNHCHR, 2006) can be adapted to HRBA in policies and programmes pertaining to nuclear technologies. Such guidance is helpful because it provides additional ethical support for a human rights based approach. The following are principles that may be derived from including such guidance into the approach:

- The main objective of nuclear policies and programmes should be to fulfil human rights, in particular the right to sustainable energy.
- Nuclear policies and programmes should identify the right-holders and their entitlements, corresponding duty-bearers and their obligations, and work towards strengthening the capacities of rights-holders to make their claims and of duty-bearers to meet their obligations (the current emphasis in the nuclear context in many countries is on ‘stake-holders’, not ‘right-holders’).
- Principles and standards derived from international human rights treaties should guide all policies and programmes in the nuclear sector and in all phases.

As the above principles indicate, the right to sustainable energy is considered a fundamental ethical right. The emphasis on the right to sustainable energy will not be productive unless it is firmed up. Pinning it down would provide firm ground for a progressive framework of energy management. Energy is essential for development. Just as food is a source of energy for human development, so are renewable and non-renewable sources of energy essential for economic growth and social well-being. If there is a right to development, then there exists a right to sustainable energy.

The right to development is an inalienable and indivisible human right ‘by virtue of which every person and all peoples are entitled to participate in, and contribute to, and enjoy economic, social, cultural and political development, in which all human rights

and fundamental freedoms can be fully realised' (Art.1, RtD Declaration). The right to development is both, a substantive right, and a right to a process of development. The process, which as expressed in the human rights based approaches to development (HRBA, 2003), should be universal and inalienable, indivisible, interdependent and inter-related, non-discriminatory and equal, participatory and inclusive, accountable, and be situated in the rule of law. The right itself then, as society progresses, includes not only food and shelter but also energy. Humans, as hunter-gatherers, may not have dreamed of classifying food as a human right, as food was a matter of reward for the fittest and ablest amongst them. However, as society developed farming and became more settled, food became abundant and it became abhorrent for anyone to go without food. Hence we arrive at today's situation where food is classified as a human right. So too should be the right to sustainable energy. It is rightly arguable then, that the right to sustainable energy is a component of the right to development. Such a right should be fulfilled in a manner that respects human rights. It is the duty of States to 'co-operate with each other in ensuring development and eliminating obstacles to development' (Article 3(3) RtD Declaration). Article 4 reinforces this duty by stipulating that States should 'take steps, individually and collectively, to formulate international development policies with a view to facilitating the full realization of the right to development'.

Ethical issues are encountered from experience. For instance, in the human rights based approach, individual and collective rights aspects also require special attention. Collective rights are called into question during various circumstances such as individual versus collective radiation doses, rights of the local community waste hosting repositories, and rights of the communities during transportation of nuclear material. Nuclear energy policies need to be explicit in addressing both individual and collective rights in human rights based approach.

Further declarations and sources of law and authority will need to be included. For instance, according to the 1997 Declaration by the UNESCO Director-General, on the human right to peace, lasting peace is a prerequisite for the exercise of all human rights and duties.¹⁶³ The human right to peace, unlike the right to development, is a negative right. It restrains states from going to war and stipulates against the use of force. On the other hand, it can also be taken to mean that use of force is necessary in the face of unjustified aggression, in order to restore peace. The maintenance of balance of power through a stockpile of nuclear arms can be presented as a deterrent to disturb the peace. This right needs to be at the centre of all developmental and military research budgets that feed into nuclear technologies. This also requires a rights-based approach to international obligations arising out of treaties such as the Nuclear Non-Proliferation Treaty (NPT) and Strategic Arms Reduction Treaty (START).

The right to peace can be readily associated with the right to peaceful uses of nuclear technology, under the NPT. An escalation in peaceful use of nuclear technology will contribute quantitatively in securing development (p.5). Keeping in perspective the transformation that the NPT is undergoing in recent years, it comes as no surprise that

163 Director-General, 1997. The Human Right to Peace: Declaration by the Director-General, UNESCO (SHS-97/WS/6).

the fundamental bargain of NPT – the institutionalisation of the ‘nuclear haves’ and ‘nuclear have-nots’, is coming under fire. The recent review of the Treaty produced fresh momentum towards the abolition of nuclear weapons, by proclaiming a world free of nuclear weapons as guiding light of nuclear diplomacy in the years to come. This is a step closer to ensuring that the right to peace can be realised without the possession of weapons of mass destruction.

5.8. Ethics of Risk

As discussed in the introduction and the considerations above there are a number of principles and theories that can be applied to assist ethical policy making in nuclear energy. A contrast in philosophical viewpoints can be found between the deontological and utilitarian approach. The deontological approach emphasises justice and the procedural aspects of decision-making, while utilitarianism focuses on the outcome of policies. The utilitarian approach also includes principles of justice, mainly distributive and retributive. Utilitarianism focuses more on the ends, deontology more on the means.

Reflection on each principle in the light of each culture can be developed in the construction of policy analysis, taking into consideration the aspects mentioned in this report. According to Robertson (2009),¹⁶⁴ the principle of no acceptable risk, means a risk can never be an ‘acceptable’ risk, as a risk implies that there is a negative effect to be taken into consideration, in the hope of attaining a certain benefit. That negative effect can never be absolutely acceptable. When applied to nuclear energy, there are multiple aspects that can be considered a risk or a possible negative implication. The ones mentioned in this report are the negative effects of mining, the risk of nuclear weapons proliferation and the safety risks of nuclear reactors. Many persons have protested after Chernobyl and Fukushima accidents, using this principle, that the radiation releases are not acceptable. Some governments have also adopted that position, such as Germany. Although there is no absolute acceptable risk those negative effects should be weighed against the positive. This could make a negative effect more or less acceptable, but never completely acceptable.

In technology assessment, however, since all human activity has some risk, the relative risks of alternatives needs to be weighed against each other. The precautionary principle has been used to exercise precaution in applications where the risks are very difficult to calculate due to the novelty of the circumstance.

Resources used to address one negative aspect may leave no space to use those resources to mitigate other aspects. The principle of no free lunch could be stated in other words: *‘you don’t get anything for nothing’*. Focusing on making one powerful reactor safer may not lead to an overall improved safety level of nuclear reactors worldwide unless the research is shared. Policy should promote general research on improving the safety level and efficiency of broad classes of reactors not just one. The no free lunch principle can also be applied to mining, where the commonly stated no

164 We also acknowledge Dr. Robertson for submission of his article for use in this report.

GHG-emission of nuclear reactors needs to be calculated over total life cycle rather than just during operation of the plant, as construction, mining and decommissioning are often linked to negative effects upon the environment.¹⁶⁵ When we include and average out the costs of clean-up of nuclear accidents the costs increase significantly.

The principle of risk optimization means that if a benefit is achieved by sacrificing investment in other aspects, one should consider the consequences it has for the overall situation. Carefully examining all the risks and accordingly distributing the risk and potential benefits achieve the optimal results.

The principle that facts matters means that informed judgments are not based solely on good intentions but they need to be backed by scientific facts. One cannot take a sound decision if one has no idea about the true facts about the issue. Especially in projects of great expense and potential harm, scientific knowledge and data is quintessential, as one cannot afford to be ignorant about the true impact of certain measures and policies. This principle is challenged in the uncertainty over health impacts of low level radiation and questions of the threshold levels to permit radioactive exposure.

The principle of quantification where possible takes the facts one step further, calling for concrete data. Various nuclear monitoring institutions provide data. To rightly consider certain aspects and consider them in the decision-making process one need a quantified assessment of every variable, including each risk and benefit.

In nuclear energy ethics a number of practical aspects must be considered including the issue of waste, the safety of the technology and nuclear weapons proliferation. The ethical principle of avoidance harm is accepted widely (Rai et al., 2010).

Is the development of nuclear energy as a renewable energy resource inevitable? As stated earlier in this report, the use of nuclear energy has become necessary in providing a sustainable energy resource in combating climate change. It produces little GHG emissions, although the other activities involved in the process towards maintaining a nuclear plant, such as the mining of the fuel, should be developed more so as to truly minimise the impact on climate change.

The nuclear waste resulting from the energy production processes creates a serious problem. Especially the fact that governments usually do not provide sufficient information means that the public is misinformed on the implications of a nuclear waste site in their direct environment. This prevents a well-informed decision and does not fulfil the criterion of adequate disclosure of information and therefore the freedom of choice. This is a crucial aspect of the theory of informed consent, which generally applies to ethics. Other criteria of informed consent are consideration of the rights and interests of all parties involved and often also to provide an objective timeframe for the decision-making. The theory of informed consent is a consequence of recognizing autonomy, a principle that has been generally accepted in bioethics,¹⁶⁶ and accepted in decisions regarding use of potentially dangerous substances such as pesticides and living modified organisms (under the Cartagena Protocol to the CBD).

¹⁶⁵ See Section 1.4.

¹⁶⁶ Refer to the case study on Olympic Dam Uranium Mine in Australia in Boonlong et al. (2010).

Over the past decades many persons have objected to the general use of nuclear energy for fear of proliferation of nuclear arms and its catastrophic effects in case of armed conflict. Ethical theories have nonetheless rejected this argument in the light of increased safety and research in nuclear plants. Is developing nuclear energy worth possible global nuclear arms proliferation which would result in nuclear winter if they were used. Does the outcome outweigh the violation of human rights during even limited use? The issue remains that the recycling process of nuclear waste that is inherent to the production of nuclear energy, is difficult to monitor totally whereas an outbreak of a nuclear conflict could precede global-scale devastation. In this context the current status of climate change and technological developments should be considered. How reliable are the efforts of international organisations to monitor and hold inspections on site? Is it realistic to eventually subject nuclear plants on a global scale to international safeguards and prevent states from developing nuclear weapons with the enriched uranium or plutonium?

Overall, safety on nuclear sites is said by IAEA to be manageable. It is not said that nuclear sites are completely safe and any meltdown can be prevented, but technology has found ways of reducing a great part of the damage in unforeseen critical situations. Measures have been taken to improve the structure and internal system of the reactors, along with general procedural safety regulations. Thus far three main nuclear accidents with environmental consequences have occurred, though it is unclear whether all the lessons from minor accidents before these had been applied to making the systems safe.¹⁶⁷ Each nation needs to answer the question whether the benefits of nuclear energy outweigh the consequences of any accidents.

5.9. Sustainability

Sustainability “refers to the viability of socially shaped relationships between society and nature over long periods of time... and closely linked to “internal” problems of social structure, such as social justice, gender equality and political participation” (Becker et al., 1997, p.4). The constitutive of development, on the other hand, is in “the removal of major sources of unfreedom” (Sen, 1999, p.3) as an overarching objective rather than economic growth. This includes social objectives such as alleviation of poverty and other forms of systematic social deprivation. In this basis, and notwithstanding the contesting approaches to sustainability and, sustainable development in particular, there is a common ground between the concept of development from the view of Amartya Sen, and sustainability on the other hand. Both are normative in their demands for, “development as an expansion of human capabilities and freedom” (Sen 1999), whereas, sustainability appeals to justice and equity from regional, national and sub-national points of view and from the perspective of the future generations as well.

On the other hand, conceptions of justice and different principles of equity that are too familiar to the climate change literature (see, for example, Vaillancourt and Waub 2003; Ringius et al., 1998; Burson et al., 2008), are also considered as a part of sustainable development. Especially, from the view of the social (Munasinghe 2000; Najam et al.,

167 Three Mile Island, United States of America, Chernobyl, Ukraine, and Fukushima, Japan.

2003) and environmental (Munasinghe, 2000) dimensions of sustainability, different conceptions of justice and equity are considered to serve as mediators in distribution of benefits or sharing burdens among the members of society. It is also argued that dimensions of sustainability – be they economic, environmental, social or institutional, – should be regarded in an equitable manner.

Sustainable development demands for justice and equity are not merely as an instrument to some ends, for example, access to modern energy services, but have an end purpose in it. This is, referring to Amartya Sen, due to its overriding objective to expand human capability and substantial freedoms. For energy service, for example, this would imply that qualitative indicators like reliability, affordability or intensity of energy poverty need to be considered. In cases of conflicting objectives, a non-instrumental approach to sustainability will require us to consider compensations among those affected with due consideration of the most vulnerable.

As pointed out by Becker et al. (1997), sustainability directly linked with ‘internal’ problems of societal phenomena, therefore, it is a “topic of research that is basically social” (p.4). From this societal perspective, conventional approaches to climate change were criticized for it being: biased towards the natural science (Newby 1993; Cohen et al., 1998), exclusive or unbalanced in representation of different views and stakeholders (Watson 2000; Watson 2008); and paying little or no attention to societal aspects, for example, symbolic dimensions of social practices which allows analysis of those factors that simultaneously affect the perception and valuation of the environment and govern everyday behavior (Becker et al., 1999, p.9; see also Rai et al., 2010). Also technically defined end goals that are largely out of the societal context.

From the technology assessment perspective, this latter criticism on ‘technocratic, undifferentiated science’ (Taylor, 1997) based climate change politics is ‘tailor made’ in favour to hydro and nuclear power (Cohen et al. 1998) and leads to technological determinism (Taylor, 1997) in the name of global climate change and carbon-neutral technology.

6. Policy Options and Conclusions

The use of nuclear energy is associated with a complex set of issues requiring many ethical considerations. As nuclear energy technology becomes a more prominent issue, governments are urged to consider these issues and their attendant ethical considerations. To that end, the following policy options and conclusions are made. These options and conclusions are considered the most significant ones following the body of the report.

6.1. Reference to Ethical Principles in International Relations

First, the ethical issues present in international relations should be tackled with greater ethical considerations in mind. It may benefit the international community to provide consideration for the perspectives of developing countries, which are not technologically advanced. These countries' needs are often overshadowed by security concerns (for instance, in the GNEP), but greater measures to provide for equality may result in more stable international relationships.

6.2. More Guidelines Regarding the Implementation of Definitions

An improvement in the overall process of implementing guidelines will create more ethical and safe nuclear plants. Further explanation through detailed guidelines regarding definitions may be beneficial, as there are so many laws already. The use of terms such as "as low as reasonably achievable" (ALARA), while undoubtedly context-sensitive, would benefit from greater detail and standardization. When several guidelines are available, these should be integrated into work cultures. As mentioned above, many ethical documents and guidelines exist for nuclear facility operators, but states may benefit from more integrated guidelines. These guidelines can in turn be integrated into nuclear safety cultures through mechanisms ranging from safety guidelines to employee performance appraisals.

6.3. Nuclear Ethics in the Context of Climate Change

This report shows that there are other considerations concerning the use of nuclear power with regards to its effects on society and environment. Any thorough ethical or policy analysis of nuclear energy technology needs to consider the entire nuclear fuel cycle. While the nuclear reactor itself is not a source of GHG gas emissions, negative externalities associated with uranium extraction and the problem of toxic radioactive wastes and their disposal cannot be ignored.

There are factors that can have far reaching economic consequences if states do not work towards establishing a common ethical rule that will safeguard the energy policies of countries wishing to pursue an active nuclear program for civil purposes. Both, the front end and the back end of the fuel-cycle should be considered to avoid an

incomplete cost-benefit analysis. If uranium mining is not considered when deciding nuclear energy technology policy, it can lead to states not considering the health and environmental effects on uranium-mining countries and their populations.

6.3.1. Nuclear Technology and UNFCCC

In the following discussion we consider different perspectives on the potential role of nuclear energy technology from a view of the ultimate objective of the United Nations Framework Convention on Climate Change (UNFCCC), that is, to achieve a ‘...stabilization of greenhouse gas concentrations...’ as well as ‘...to enable economic development to proceed in a sustainable manner’ (Article 2). Sustainable development is among the principles of UNFCCC as ‘Parties have a right to, and should, promote sustainable development’ (Article 4). Furthermore, these two elements of UNFCCC’s objective – climate change and sustainable development – are emphasized in the Kyoto Protocol as well. Especially, when it concerns the clean development mechanism (CDM), climate change and sustainable development are of equal importance and required to be fulfilled in parallel.

Let us consider the relevance of nuclear technology narrowly from the climate change perspective; followed by a synergy between climate change and sustainable development upon which a role and status of nuclear technology shall be assessed further.

Since the Fourth Assessment Report (4AR) of the Intergovernmental Panel on Climate Change (IPCC) in 2007, there is increasing evidence and detailed data in support to its statements on detection and attribution of climate change to anthropogenic forces. Although we have improved understanding of the effects of climate change on ecosystem, sea level rise and extreme weather events but some gaps remain in relation to human health, agriculture and food security (see Fussel, 2008; Warren et al., 2009; IPCC, 2010). In addition, several sources had come to more alarming conclusions than those projected in IPCC’s 4AR. It is observed that volume and extent of Arctic sea ice decrease is continued with a sudden shrink to a new record low in 2007 and at a rate which by far exceeded the range of previous model simulations (Haeberli, 2009); emission of greenhouse gases is raising higher than IPCC’s worst case scenario (Lemons and Brown, 2011); and climate change impacts on forests and ecosystem extinction are more severe than in IPCC’s 4AR (Warren et al., 2009).

Stimulated by these disturbing facts, there are growing studies and policy options on greater use of non-emitting technologies, including nuclear technology. From this climatic-environmental enquiry, a nuclear technology has been seen as “*the largest and lowest cost GHG reduction potential in power generation*” (IAEA, 2009a) and “*on these features,*” as IAEA maintains, “*its merits with respect to climate change that it should be judged in climate change deliberations*” (IAEA, 2009b). Further considerations such as energy security and economic growth also warrant that the global roadmap for technology development and deployment must focus on nuclear power and sources for renewable energy (Tomlinson, 2009). An update of influential study on *The Future of Nuclear Power* by Massachusetts Institute of Technology has similar grounds on why we should greater utilize the potential of nuclear energy.

“In sum, compared to 2003, the motivation to make more use of nuclear power is greater and more rapid progress is needed in enabling the option of nuclear power expansion to play a role in meeting the global warming challenge. The sober warning is that if more is not done, nuclear power will diminish as a practical and timely option for deployment at a scale that would constitute a material contribution to climate change risk mitigation.” (MIT, 2009. p.4).

On the other hand, it is apparent that the ongoing negotiations on further commitments on emission reductions for Kyoto Protocol Annex-I countries has opened up the opportunity for a renewed interest on previous debate on ‘eligibility’ of nuclear technology under the CDM. It should be reminded that for the first commitment period of the Kyoto Protocol, 2008–2012, nuclear technology was ruled-out from CDM by the Decision 5/CP.6 which states that countries “...included in Annex I are to refrain from using emission reduction units generated from nuclear facilities to meet their commitments under Article 3.1” (FCCC/CP/2001/L.7). And studies, for example Briefing paper on Nuclear Power (2008) by Energy Research Center of the Netherlands, commissioned by The Climate Group and UK former Prime Minister Tony Blair, suggests that “inclusion (nuclear technology) could help deployment of nuclear energy in developing countries through the transfer of finance and technology from industrialized countries” (Bakker 2008, p.10) and, further recommending to “initiate discussions on eligibility of nuclear energy under the Clean Development Mechanism in the Ad Hoc Working Group on further commitments under the Kyoto Protocol” (p.3). In fact, draft amendment text to the Kyoto Protocol by the Ad Hoc Working Group for Further Commitments for Annex I Parties under the Kyoto Protocol, as of June 2011, includes an option for nuclear facilities “... that commenced operation on or after 1 January 2008 shall be eligible under the clean development mechanism in the second and subsequent periods” (AWG, 17 June 2011). This, as stated on the web page of IAEA’s Planning and Economic Studies Section, “An important issue for nuclear power will be the fate of its current exclusion from CDM and JI (joint implementation).”

6.3.2. Climate Change and Sustainable Development

It is argued that the divide between climate change and sustainable development, as the latter term traditionally goes under the headings of social and political sciences, has its roots in disciplinary boundaries between the natural and social sciences. They have differing epistemologies and theories (Newby, 1993), distinct discourses, methods and research cultures (Cohen et al., 1998; Becker et al., 1999). The demarcation problem between these two disciplines, also known as Kuhn – Taylor debate (see Kuhn 2002; Nickles 2006; Dorjderem 2011), has become apparent in regard to the problem of global climate change. Respectively,

“the reductionism of the dominant natural science approach to CC (climate change) has constructed it (the climate change) as an environmental problem amenable to scientific analysis, this formulation has not been especially helpful in figuring out how to respond politically because it ignores the human dimensions of the problem... . By contrast, the human-centered SD (sustainable development) approach to environmental problems is more politically and geographically sensitive, but it is analytically vague.” (Cohen et al.

1998, p.342).

“the science driven nature of the CC debate – characterized by a form of physical reductionism – and the problem driven (and also actor focused) nature of SD field – characterized by a more human behavior centered approach.” (Cohen et al. 1998, p.343).

From this perspective, the traditional approach to climate change as an environmental problem was largely based on scientifically defined targets, wherein interference is typically based on assessment of state of the environment and impact with a view to define policy responses. In this endeavor, social processes and social science contribution can be mainly considered in connection to achieve these scientifically pre-defined goals, the goals that derived from the analysis of physical environment and thus, detached from their societal framework (Cohen et al., 1998; Becker et al., 1999). This ‘retrospective’ approach, wherein societal processes and their interactions with environment are formulated in non-social terms or divorced from its social context (Newby 1993 quoted in Cohen et al., 1998; Becker et al., 1999) was exemplified in IPCC’s First and Second Assessment Reports (Cohen et al., 1998) and also are embodied into its working groups as follows. The first working group was assigned to examine scientific assessment of climate change, and the second working group focused on environmental and socio-economic impacts, driving forces, and finally, the third working group defines the response strategies. This way of knowledge production is highly hierarchical by nature, options for each succeeding stage in the chain of climate science – impacts – policy response is dependent on the outputs of the previous one, that is, ultimately all are based on physical climate science (Taylor, 1997; Cohen et al., 1998). This in turn, leads to environmental (Taylor, 1997) and technological (Cohen et al. 1998) determinism dominated by predefined ‘instrumental or end-purpose rationality’ (Tribe, 1972; Cohen et al., 1998) which sets the direction in selecting the most efficient means to those ends. And society has to adjust to these ends, the parameters of which were set by climate science (Taylor, 1997; Cohen et al., 1998).

Science based environmental approach has another feature that climate change is the global and common concern of humanity. By this, as described in Lucia, modern science separated *nomos* from *ethos* and thereby ignored the importance of locality and particularity (2009). This global environmentalism, as Taylor argues, with its undifferentiated moral-technocratic politics on climate change, is *“not only unlikely to achieve their intended effects but likely to produce undesired ones”* (1997). Countries involved in the negotiations process for the Framework Convention on Climate Change (FCCC) took similar divisions; while for industrialized nations climate change is seen as an environmental problem, it is a development problem for the South (Cohen et al. 1998; Olsen, 2007; Boisson de Chazournes, 2008). Until the establishment of a Intergovernmental Negotiating Committee for a FCCC, the environmental problem based approach to climate change was not acceptable for the developing nations on the ground that *“their concerns were not properly addressed by the scientifically focused IPCC process and rejected the proposal of a negotiating committee that would work under the auspices of WMO and UNEP”* (Boisson de Chazournes, 2008).

It is argued that environmental problem and development based approaches to climate change were interconnected until IPCC’s Third Assessment Report (3AR). In

addressing this shortcoming, the IPCC, under the chairmanship of Robert Watson, had a series of regional meetings on Development, Sustainability and Equity, in a view to adequately address and integrate it into the work of IPCC.

6.3.3. Kyoto Protocol and Nuclear Technology

As defined in paragraph 2 of Article 12 the purpose of CDM is, first, to assist industrialized nations in meeting their emission limitations and reduction commitments through a cost-effective way. The reference technology is typically carbon-intensive and because of the bigger GHG emission potential (Muller-Pelzer, 2004) the emission reduction projects in developing countries are least costly compared with ones in Annex-I countries. Second, by bringing the foreign investment and transfer of carbon-neutral technologies, as a part of the CDM project, it aims to assist the developing countries to achieve sustainable development. It is underlined that “achieving sustainable development is a purpose of the CDM on equal terms with the reduction of GHG emissions” (Olhof et al., 2004). With this dual purpose, CDM is also called “a bridge between the North and South” (Olsen, 2007); for industrialized countries it is a cost-effective way in their commitment to reduce GHG, for developing countries it is an opportunity to achieve sustainable development through the foreign capital flow and clean technology transfer.

From the point of UNFCCC’s ultimate objective, which is to stabilize “greenhouse gas concentration in the atmosphere at a level that would prevent dangerous human induced interference with the climate system” (Article 2), all types of technologies must have been welcomed as long as they contribute to this objective, including the nuclear technology. It is reported that nuclear energy is one of the least carbon intensive. OECD Nuclear Energy Agency’s estimation suggests that the emission from the full energy chain amounts to only about 2.5-5.7 grams of GHG per kWh of electricity produced (gCeq/kWh) (OECD, 2002). Whereas IPCC (2011)’s SRENN Report, which is based on review of 2,165 published references of lifecycle assessments of electricity generation technologies to estimate the lifecycle of GHG emissions from electricity generation technologies, shows that nuclear technology is ‘cleaner’ and more sustainable compared to natural gas, oil and coal. Yet, it remains a so-called ‘dirty technology’ if we refer to solar, bio-power, geothermal, ocean, hydro and wind energies (IPCC, 2011, p.13).

This emission intensity based judgment is a statistical aggregate. But if the full life cycle of nuclear technology is viewed from upstream (uranium exploration, mining and transport) and downstream (decommissioning and waste management of nuclear power plants) related operations separately, those countries in downstream operations are in a better-off position compared to the upstream countries. These range between 0.74 – 1.3 g CO₂eq/kWh and 1.5 – 20 gCO₂eq/kWhe, respectively. On the contrary, fossil fuel at upstream accounts up to 25% of emissions (Weisser D, et.al. 2008). From the climate change perspective, then, uranium mining in developing countries is encouraged compared to similar operations in Annex I countries. In the situation when upstream and downstream operations are both in Annex-I countries, those who are consumers of nuclear electricity or the downstream country, are in a

better-off position from a climate change perspective as they emit less.

It should be noted that the above mentioned reports on GHG life cycle assessment didn't consider the land use and land-use change related emissions. Direct emission from nuclear power ranges around 0.74–1.3 gCO₂eq/kWh, yet it is ranked the higher/worse with respect to unit size under the technology risk matrix (Weisser et.al., 2008). In other words, if we refer to the purpose of CDM, then a stabilization of emissions and its reduction is not the only criteria to judge certain technologies. Any projects under the CDM must meet the requirements of additionality and also co-benefit the developing country in such a way that is consistent with sustainable development. In this connection, it is worth to recall that majority of EU, as well as countries including New Zealand, Indonesia, and the Alliance of Small Island Developing States (SIDS) and OPEC members¹⁶⁸ were against to include the nuclear energy into the flexibility mechanisms.

Arguments against the inclusion is that nuclear energy technology does not meet the concept of clean development on the ground that the full cycle of nuclear fuel – energy use for uranium extraction, conversion, enrichment, nuclear plant construction and decommissioning, spent nuclear fuel reprocessing and recycling – is not sustainable. Another argument which is strongly voiced specially by least developing nations is that inclusion of nuclear energy technologies under the CDM will reflect current investment flows that is biased towards high-growth countries. Even without nuclear energy, the current trend for CDM projects supports this anticipation. From 76 countries that host CDM projects, countries such as China, India and Brazil receive most of these projects (Michaelowa and Müller, 2009).

This latter picture on unequal access to low carbon technology and related investment also means that CDM, largely discounting its element to assist developing countries in achieving the sustainable development, seems to be governed alone by economic issues (carbon trade). Moreover, with reference to sovereignty, no definition and criterion were given to this second objective of CDM – the sustainable development. Instead, it was to developing countries to decide what is sustainable from their perspective. In literature, its side effect is termed as 'race to the bottom' when developing countries in their attempt to attract CDM projects do lower their standards related to development. In this regard, some sources reported that two elements of CDM objective – emission reduction and sustainable development – are attainable for high impact projects. They either contribute to emission reduction or to sustainable development (2007).

As earlier mentioned, it is up to developing countries to decide the parameters of sustainability. Therefore, any decision on use of nuclear technology is conditional to its economic attractiveness, with some concern also given to energy security reasons. Otherwise, to make workable the alleged climate change 'merits' of nuclear technology, there are more requirements that are beyond the scope of UNFCCC. One of the critical

168 See, for example, The Clean Development Mechanism: An instrument for sustainable development or a new nuclear subsidy? Nuclear Information and Resource Service. Also, Summary of the Sixth Conference of the Parties to the Framework Convention on Climate Change: 13-25 November 2000. Earth Negotiations Bulletin, Vol. 12, No. 163, Nov. 2000; Nuclear lobby at Poznan COP-14: sneak in through the back door. Nuclear Monitor, No. 681, 18 December 2008.

policy options for each nation is the definition of sustainability, however, if there are continued delays in global agreements sustainability seems further away.

6.4. More Favourable Alternatives to Nuclear Energy Technology

States may consider “safer” options when using nuclear energy technology. With respect to nuclear reactor design, states may wish to provide consideration for meltdown-resistant designs. With respect to enrichment, states may wish to consider purchasing enriched uranium or having it enriched elsewhere. This is a difficult choice for states, as they may wish to increase energy security by developing their own enrichment capacities. Nevertheless, they are options. With respect to reprocessing, states may wish to consider not reprocessing fuel or taking extra security precautions when doing so. Alternatively, they may consider increasing funding for more proliferation-resistant reprocessing technologies and/or consulting groups such as GNEP. With respect to depleted uranium, states may wish to consider restricting its use to civilian purposes and disallow military use. States may also wish to consider supporting the banning of depleted uranium weapons.

6.5. Greater Transparency of Nuclear Information

Societies will benefit from greater exchange and transparency of nuclear information. It was mentioned in this report that the general public often feels that it does not have enough access to nuclear safety information, making it difficult for them to take part in policy and ethical debates. The public may further not feel comfortable with nuclear energy if there are suspicions that information is being hidden, the media is controlled by industry. The failure to disclose information in a timely manner is one of the concerns of the Chernobyl and Fukushima accidents. The efficacy of public discourse and acceptability of nuclear decisions by policy-makers, will be increased if nuclear safety information is provided with greater transparency.

6.6. Alternative Measures to Safeguarding Nuclear Proliferation

While most states take concrete steps to curb nuclear proliferation, there are other steps that may be underemphasized. As mentioned in this report, a more integrated approach to countering this threat may be beneficial. Tactics may need to shift from a predominantly technology and fissile material stock monitoring approach to targeting terror financing and social capital. Moreover, states may benefit from designing a complex fabric of nuclear security on a socio-technical basis. This may involve educating citizens, politicians, and policy-makers to the security implications of nuclear technologies and implementing complex security measures without causing alarm.

6.7. Realistic assessments of costs and implications

The cost of nuclear energy should be more completely assessed by taking into

consideration the opportunity cost vis-à-vis other energy sources and all “hidden” costs. These were mentioned in this report, and include insurance guarantees, the cost of decommissioning plants, regulatory oversight, non-monetary “safety” costs, and environmental costs, among others. The total costs for other energy sources should also be considered.

6.8. Greater Equality for Developing Countries

The ethical issues present in international relations should be tackled with greater ethical considerations in mind. It may benefit the international community to provide consideration for the perspectives of developing countries, which are not technologically advanced. These countries’ needs are often overshadowed by security concerns (for instance, in the GNEP), but greater measures to provide for equality may result in more stable international relationships.

6.9. More Ethics in International Agreements

Nuclear agreements should be analyzed with significant emphasis on ethical aspects. The ethical issues should be identified (Rai et al., 2010), common definitions developed and standardized despite different worldviews, and various nuclear agreements can benefit from integration in a more cohesive and unified regime.

6.10. Increased Importance of Equity and Justice

Greater application of ethical principles such as justice and equity may provide a reason to consider the opportunity cost to the impoverished when considering such spending. This may also prompt developing countries to spend comparatively less on nuclear technology and provide greater financial attention to the impoverished. Finally, to meet the ethical obligation of justice, developed countries may provide funding and development assistance or technology transfers and cooperation with developing countries.

6.11. Human Rights-Based Approaches

Given the complexity of nuclear energy, it may be useful to examine the imperatives of policies, treaties, and programmes on nuclear energy in light of a human-rights based approach, which can be found among the countless documents and understandings produced. The right to sustainable energy is not yet recognised as a human right, but when placed within the right to development, it can be argued that in a society where progress is fundamental to its identity, the right to sustainable energy has a strong case as a human right. It would be unethical to not persistently explore ways and means to establish the human right to sustainable energy. The human rights-based approach is able to simplify some of complexity resulting from international politics as well as the procedural complexities involved in the implementation of myriad nuclear agreements and regulations. Nuclear energy development would be considered more

ethical if the infringement on human rights would also be limited.

It is therefore in our interest to invest in improved safety regulations and technology, so as to prevent further violation of the human rights involved. Modern reactor designs can achieve a very low risk of serious accidents, but “best practices” in construction and operation are essential. The suppliers of nuclear materials should take up research in this area. It is within the theory of deontology to adhere to procedures and rules and eventually decide whether breaching the rules in a process is worth the outcome or result. Utilitarianism would consider that the infringement of certain rules or procedures is compensated by the outcome. Human rights are considered by some philosophers as an expression of those rules or procedures and therefore are generally most supported by the deontological school of ethics.

6.12. Provide Effective Measures Against Misuse of Nuclear Waste

Geological disposal is technically feasible but execution is yet to be demonstrated or certain. A convincing case has not been made that long-term waste management benefits of advanced, closed fuel cycles involving reprocessing of spent fuel are outweighed by the short-term risks and costs. Improvement in the open, once through fuel cycle may offer waste management benefits as large as those claimed for the more expensive closed fuel cycles. The company, which sells nuclear fuel, should take up the moral responsibility of disposing the nuclear waste also without any additional cost.

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Appendix: Information on Nuclear Reactors

Table 23: Nuclear power plants in commercial operation

Reactor type	Main Countries	Number	GWe*	Fuel	Coolant	Mod
Pressurized Water Reactor (PWR)	USA, France, Japan, Russia, China	265	251.6	enriched UO ₂	water	w
Boiling Water Reactor (BWR)	USA, Japan, Sweden	94	86.4	enriched UO ₂	water	w
Pressurized Heavy Water Reactor 'CANDU' (PHWR)	Canada	44	24.3	natural UO ₂	heavy water	heav
Gas-cooled Reactor (AGR & Magnox)	UK	18	10.8	natural U (metal), enriched UO ₂	CO ₂	gra
Light Water Graphite Reactor (RBMK)	Russia	12	12.3	enriched UO ₂	water	gra
Fast Neutron Reactor (FBR)	Japan, Russia	2	1.0	PuO ₂ and UO ₂	liquid sodium	n
Other	Russia	4	0.05	enriched UO ₂	water	gra
TOTAL		439	386.5			

*GWe = capacity in thousands of megawatts (gross)

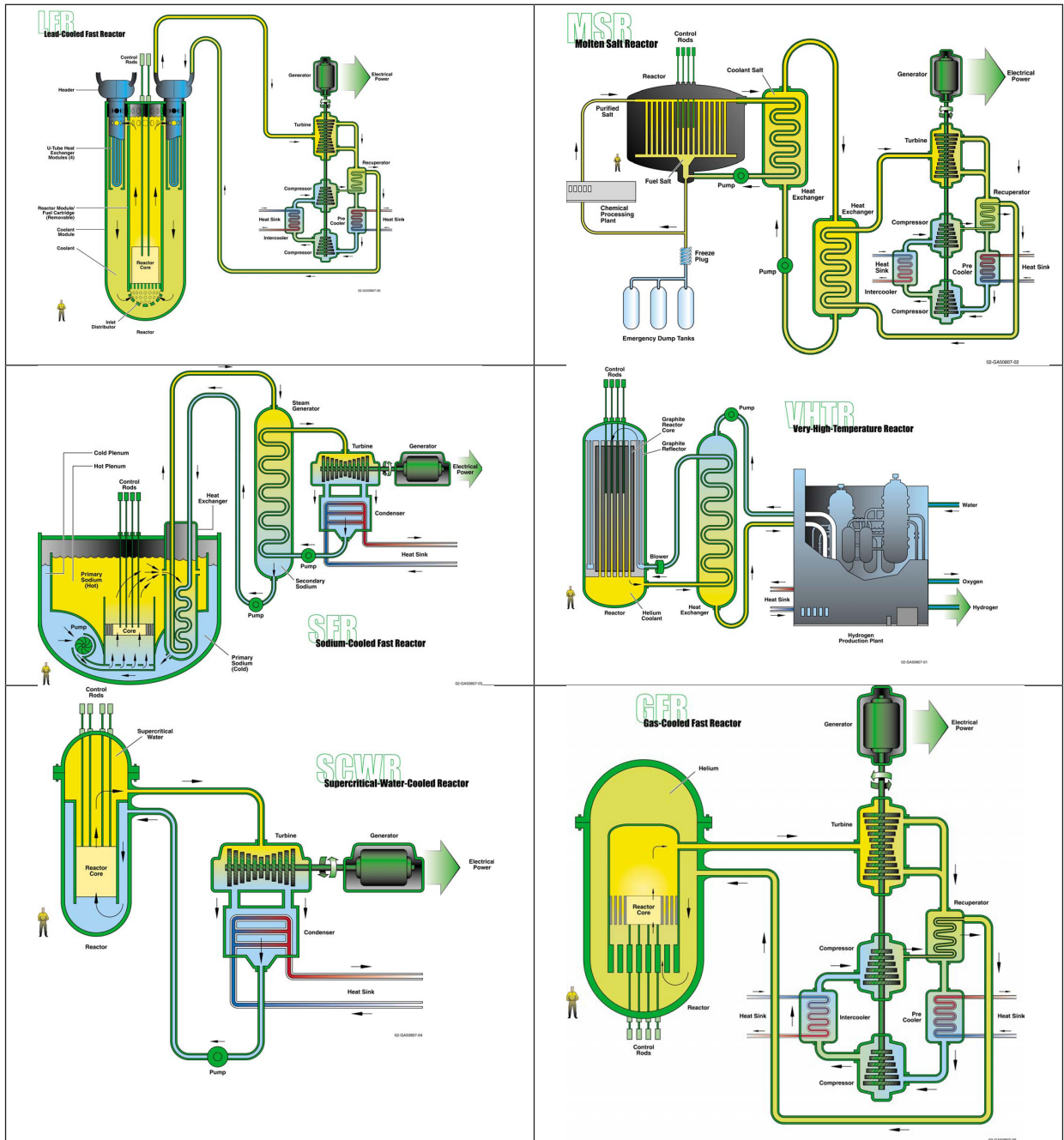
Source: *Nuclear Engineering International Handbook 2010*

Table 24: Nuclear power plants under construction by reactor type

Reactor Type	Country (Reactor/s)	
Pressurised Heavy Water Reactor (PHWR)	Argentina (Atucha 2)	
	Canada (Bruce A1, Bruce A2, Point Lepreau 1)	
	India (Kaiga 4, Kakrapar 3, Kakrapar 4, Rajasthan 7, Rajasthan 8)	
	Romania (Cernavoda 3, Cernavoda 4)	
Pressurised Water Reactor (PWR)	Bulgaria (Beleno 1)	
	China (Qinshan phase II-4, Hongyanhe 1, Ningde 1, Sanmen 1, Ningde 2, Yangjiang 1, Taishan 1, Fangjiashan 1, Fuqing 1, Hongyanhe 2, Sanmen 2, Haiyang 1, Ningde 3, Hongyanhe 3, Hongyanhe 4, Yangjiang 2, Taishan 2, Fangjiashan 2, Fuqing 2, Changjiang 1, Yangjiang 3, Haiyang 2, Ningde 4, Hongyanhe 5, Fangchenggang 1, Changjiang 2, Hongshiding 1, Taohuajiang 1, Fuqing 3, Yangjiang 4)	
	Finland (Olkilouto 3)	
	Russia (Kalinin 4, Vilyuchinsk, Novovoronezh II-1, Leningrad II-1, Rostov 3)	
	Novovoronezh II-2 Leningrad II-2 Rostov 4 Baltic 1 Leningrad II-3)	
	Republic of Korea (Shin Kori 2, Shin Wolsong 1, Shin Wolsong 2, Shin-Kori 3, Shin-Kori 4, Shin-Ulchin 1, Shin-Ulchin 2)	
	France (Flamanville 3)	
	Pakistan (Chashma 3 Chashma 4)	
	India (Kudankulam 1, Kudankulam 2)	
	Iran (Bushehr 1)	
	Slovakia (Mochovce 3, Mochovce 4)	
	USA (Watts Bar 2)	
	Ukraine (Khmelnitsky 3 Khmelnitsky 4)	
	Fast Breeder Reactors (FBR)	India (Bhavini)
	Advanced Boiling-Water Reactor (ABWR)	China, Taiwan (Lungmen 1, Lungmen 2)
Fast Neutron Reactor (FNR)	Japan (Shimane 3 Ohma)	
High Temperature Reactor (HTR)	Russia Energoatom	
Advanced Pressurized Water Reactor (APWR)	China	
	Japan	

Source: adapted from WNA information papers

Figure 25: Generation IV nuclear reactors based on 6 different technology designs



Source: Idaho National Engineering and Environmental Laboratory, INEEL.

Table 25: Impact pathways of health and environmental effects included in the externality studies of energy and transport in the ExternE Project.¹⁶⁹

Impact Category	Pollutant / Burden	Effects
Human Health – mortality	PM ₁₀ ^a , PM _{2.5} ^b , SO ₂ , O ₃	Reduction in life expectancy due to short and long time exposure
	Heavy Metal (HM), Benzene, Benzo-[a]-pyrene, 1,3-butadiene, Diesel particles, radionuclides	Reduction in life expectancy due to short and long time exposure
	Accident risk	Fatality risk from traffic and workplace accidents
	Noise	Reduction in life expectancy due to long time exposure
Human Health – morbidity	PM ₁₀ , PM _{2.5} , O ₃ , SO ₂	Respiratory hospital admissions
	PM ₁₀ , PM _{2.5} , O ₃	Restricted activity days
	PM ₁₀ , PM _{2.5} , CO	Congestive heart failure
	Benzene, Benzo-[a]-pyrene, 1,3-butadiene, Diesel particles, radionuclides, Heavy Metal (HM)	Cancer risk (non-fatal) Osteoporosis, ataxia, renal dysfunction
	PM ₁₀ , PM _{2.5}	Cerebrovascular hospital admissions, Cases of chronic bronchitis, Cases of chronic cough in children, Cough in asthmatics, Lower respiratory symptoms
	Mercury	Loss of IQ of children
	O ₃	Asthma attacks Symptom days
	Noise	Myocardial infarction, Angina pectoris, Hypertension, Sleep disturbance
	Accident risk	Risk of injuries from traffic and workplace accidents
	Building Material	SO ₂ , Acid deposition
	Combustion particles	Soiling of buildings
Crops	NO _x , SO ₂	Yield change for wheat, barley, rye, oats, potato, sugar beet
	O ₃	Yield change for wheat, barley, rye, oats, potato, rice, tobacco, sunflower seed
	Acid deposition	Increased need for liming
	N, S deposition	Fertilizing effects
Global Warming	CO ₂ , CH ₄ , N ₂ O	World-wide effects on mortality, morbidity, coastal impacts, agriculture, energy demand, and economic impacts due to temperature change and sea level rise
Amenity losses	Noise	Amenity losses due to noise exposure
Ecosystems	Acid deposition, nitrogen deposition, SO ₂ , NO _x , NH ₃	Acidity and eutrophication, 'PDF' of species
		'PDF' of species

^a) Particles with an aerodynamic diameter < 10 µm, including secondary particles (sulphate and nitrate aerosols)

^b) Particles with an aerodynamic diameter < 2.5 µm, including secondary particles (sulphate and nitrate aerosols)

Table 26: Maximum liability of the Operator and the Government in the top 10 nuclear power generating countries and India. (Civil Liability for Nuclear Damage Bill 2010)

Country	Total generation (MW(e))	Operator's Liability (USD million)	State Compensation (USD million)	Total Liability* (USD million)
United States	1,00,683	11,900	Unlimited	Unlimited
France	63,130	861	300	1,161
Japan	46,823	Unlimited	Unlimited	Unlimited
Russia	22,693	No amount specified	Unlimited	Unlimited
Germany	20,480	Unlimited	2,500	Unlimited
South Korea	17,705	474	Unlimited	Unlimited
Ukraine	13,107	237	Unlimited	Unlimited
Canada	12,569	71	Unlimited	Unlimited
United Kingdom	10,137	228	50	278
Sweden	9,041	474	198	672
India**	4,189	109	345	454

Sources: Various Sources¹³; PRS.

* Values have been converted into USD in source document as of December 2009.

** The values for India have been taken from the Bill and calculated at current exchange rates.

Sources? xxx

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