

The Future of Nuclear Energy

Background Guide

Topic: the Future of Nuclear Energy



Background and History of Council

The World Energy Council (WEC) is the foremost multi-energy organization in the world today founded in 1923 with the Mission being "To promote the sustainable supply and use of energy for the greatest benefit of all people" and the Object being "to promote the sustainable supply and use of energy for the greatest benefit of all people". Over nearly 100 years of history, WEC has Member Committees established in nearly 100 countries, which represent over 3000 member organizations including governments, industry and expert institutions. The organization covers all types of energy resources and technologies, including coal, oil, natural gas, nuclear, hydro, and renewables. From birth, WEC has always been non-governmental and non-commercial and thus has been perceived as objective and realistic in its analyses as well as agendas for action.

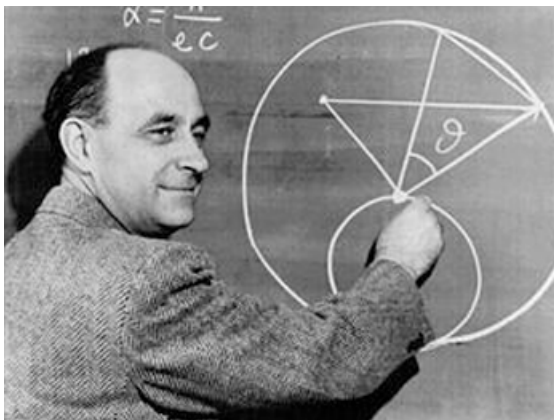
The World Energy Council consists of three separate organizations. The first is the main body, World Energy Council, which is a charity incorporated under the laws of England and Wales. The second is WEC Services Limited, the trading subsidiary of World Energy Council. The third is the WEC Foundation, which was formed in 1990 to receive and use financial contributions and donations from individuals, organizations and global energy companies.

Introduction to the Issue

OVERVIEW

The future of nuclear power stands at a crossroads after the latest disaster at Fukushima Daichi in Japan. On one hand, there is an apparent imminent nuclear renaissance as efforts to make primary energy supply more sustainable encourage diversification including nuclear, and the proliferation and safety risks associated with them act as deterrents. The negative public perception of nuclear reactors has also served to put political will in stasis and there is no consensus about the direction of the development of this technology. As individual countries struggle to make trade-offs and formulate a coherent roadmap, the World Energy Council is the most appropriate forum to discuss cross cutting issues and develop consensus to give direction to public and international policy as well as mobilize political will, funding etc to ensure the required exploitation of this energy resource. This backgrounder will explore all facets of nuclear energy from its early development to the technology associated with it.

PART I: HISTORICAL DEVELOPMENT OF NUCLEAR ENERGY



EARLY DEVELOPMENT: 1939-1946

Nuclear fission is a process in which the nuclei of certain types of atoms split, releasing massive amounts of energy. Its discovery in Nazi Germany sparked a race to harness nuclear energy for military purposes. Allied scientists soon began to

ensor publications on fission and related research to prevent the spread of this information. Albert Einstein writes a letter to United States President Franklin D. Roosevelt warning of a threat of a thermo-nuclear incendiary device the Germans are working on which compels him to sanction the Manhattan Project which ultimately develops and successfully tests the nuclear bomb which is used to carry out the '49 Hiroshima-Nagasaki twin bombings. Building on discoveries in nuclear fission, scientists at the University of Chicago produce the world's first self-sustaining nuclear chain reaction. Led by Enrico Fermi, the team successfully makes a makeshift nuclear reactor by controlling the chain reaction in a squash court of granite blocks.

President Dwight D. Eisenhower delivers his visionary Atoms for Peace speech to the United Nations General Assembly. "Atoms for Peace" marks a desire to encourage nuclear assistance and opens an era of global nuclear cooperation. Aware of the relationship between the risks and benefits of the atom, Eisenhower outlines a plan to promote worldwide the civilian benefits of nuclear science and proposes the creation of an international agency devoted to developing peaceful nuclear technologies. This leads to the establishment of the International Atomic Energy Agency. However, Atoms for Peace also spreads dual-use technology and knowledge around the world.

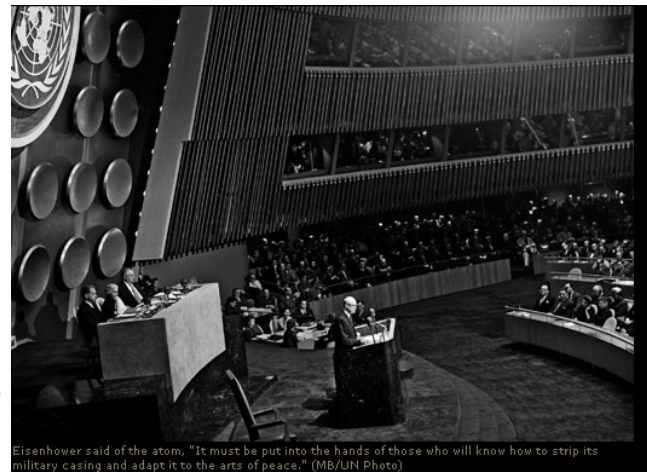


Photo: President Eisenhower delivers "Atoms for Peace" speech in UNGA Hall

Scientists in the Soviet Union, as well as in Western countries, discover that the tremendous amounts of heat released by nuclear reactions can be captured and converted into electricity. The first nuclear-powered electricity generator begins to operate in Obninsk, near Moscow.

THE EMERGENCE OF NUCLEAR POWER: 1970's- 1990's



Around the world, through the 1950s and 1970's, nuclear power found its first military application in the form of

nuclear submarines. Nuclear technology revolutionizes navies, as nuclear vessels require less-frequent fueling and thus can operate less conspicuously than their conventionally powered counterparts. The United States launches the world's first nuclear-powered submarine, the USS Nautilus. The Soviet Union also develops a nuclear navy during the 1950s. The United Kingdom follows during the 1960s, and France during the 1970s.. Nuclear navies in turn influence developing civilian nuclear industries, as they create human capital with experience required to operate commercial nuclear installations.

The first commercial nuclear power plant is inaugurated in USA running on a combination of natural and highly enriched uranium (HEU). During these years, Canada, France, and the United Kingdom also connect to their electricity grids commercial nuclear power stations of varying designs. Two major types are popular: boiling water and steam pressurized reactors.

In 1973, in response to U.S. support of Israel in the Yom Kippur War, Arab states in the Organization of Petroleum Exporting Countries (OPEC) embargo oil to the United States and cut production, causing the price of crude oil to quadruple. The U.S. government and many European countries implement rationing and price controls in response. Realizing its vulnerability to oil imports and lack of coal reserves, France decides to secure its electricity supply through heavy investment in nuclear power. The country is now a world leader in nuclear technology. The United States instead shifts its sources of electricity from mostly oil to a combination of natural gas, coal, hydropower, and nuclear. The crisis brings to the fore the vulnerability of Western countries energy security to geopolitical factors in the Middle East/



The international nuclear industry experiences its most rapid period of growth in the 1980s. During this time, over two hundred new reactors come online, mostly in Europe and Japan, and existing reactors generate more electricity through improved operation. By 1989, there are more than four hundred nuclear power reactors in thirty countries around the world.

A NEW ERA OF NUCLEAR RESURGENCE

Due in large part to concerns over greenhouse gas emissions and security of energy supply, countries around the world consider building new nuclear power plants using new types of reactors. This next generation of reactors is designed to operate at higher levels of safety and efficiency, and produce more electricity, for longer periods of time. French nuclear group Areva begins constructing the world's first such reactor in Finland. However, the project is now years behind schedule and significantly over budget.

Rapidly developing states China and India announce ambitious new targets for new nuclear plants. Although reactors are under construction in these countries, they still rely on nuclear power for a tiny fraction of their electricity needs, just 2 or 3 percent. At present, more than two-thirds of the reactors under construction in the world are in China, India, Russia, or South Korea. Many states express interest in building their first commercial nuclear power reactors, although so far only one such plant, located in Iran, is under construction.

During these years, Russia and Ukraine had several confrontations over natural gas prices. Because much of Europe's natural gas travels from Russia and through pipelines in Ukraine, the ensuing supply reductions had consequences all over the continent. The dispute causes many European governments to reevaluate their energy security policies. Countries like Germany, which voluntarily chose to phase out the use of nuclear power by 2020, and Bulgaria, Lithuania, and Slovakia, which closed some old reactors under pressure from the European Union, debate their decisions. As the nuclear reactor fleet on the continent ages and climate change goals become more ambitious--removing coal as a viable option--questions of energy security and supply diversity grow. A nuclear renaissance seems imminent but its possibility depends upon the events in the decades to come.

PART II: EMERGENCE OF CHALLENGES TO NUCLEAR POWER AND MAJOR INCIDENTS

Waste, Environmental Concerns and Nuclear Resurgence: Most nuclear countries, struggle to find permanent places to store the waste from nuclear plants or to safely dispose of nuclear waste . In 1987, US legislations is amended to allow the construction of a geological sequestration site under Yucca Mountain, in Nevada. After decades of political struggle, environmental controversy, and the expenditure of nearly \$8 billion, Yucca Mountain is still not complete. The Obama administration opposes the use of the site for nuclear waste storage and in 2010 eliminates funding for the project, a move currently



AP / Rick Gunn, File

being challenged in federal court. Italy follows Sweden in voting to phase out the use of nuclear power through decommissioning existing reactors and moratoriums on new construction. Belgium, Germany, the Netherlands, and Spain later pass similar legislation. They cite environmental, safety, and public opinion reasons. However, concerns over climate change, growing electricity demands, and security of energy supply lead many of the countries to reverse these decisions or delay their implementation through the 1990s

Non-State Actors, the Threat of Unsecured Nuclear Facilities : In the wake of the September 11, 2001, terrorist attacks, renewed fears about the security of nuclear facilities prompt regulators to take steps to enhance the security at nuclear power plants, including additional guards and more robust physical barriers. Possible terrorism risks include sabotage, attacks against the reactor cooling system, or breaching of containment structures by an air attack. In 1982 for example, eco-terrorists fire a rocket-propelled grenade at an unfinished reactor in France. Operating nuclear power plants and fuel storage sites contain large amounts of radioactive material that, if dispersed, would contaminate the environment. But carrying out an attack would be extremely difficult because nuclear plants are already engineered to withstand extreme events, with some new designs deploying additional safety and security measures. Many experts argue that the facilities are actually safer than other parts of the civilian infrastructure.

Outlier States, weak NPT clauses and clandestine weapons programs:

North Korea: After ten years of threats and treaty violations, North Korea withdraws from the Nuclear Nonproliferation Treaty (NPT), invoking Article X. The event also elicits proposals to create exit requirements in the NPT. North Korea's nuclear weapons program uses research reactors to irradiate fuel, and then other facilities separate plutonium from the spent fuel. North Korea tests nuclear



devices in 2006 and 2009; however, the extent of its nuclear capabilities and size of its fissile material stockpile remain unclear.

Syria: In September 2007, Israeli air forces execute a surprise attack that destroys a suspected plutonium–production nuclear reactor at Al Kibar, in the Syrian desert. In the aftermath of the raid, Syria levels and paves over what remains at Al Kibar and for nearly a year refuses to allow the International Atomic Energy Agency (IAEA) to inspect the site. The IAEA finds processed uranium particles there, but continued access disputes mean that the investigation remains inconclusive. Israel’s preemptive action undermines the international nonproliferation regime, because it did not allow an opportunity for international officials to attempt to inspect or collect information before the site was destroyed. Meanwhile, Syria’s lack of cooperation and refusal to join the IAEA Additional Protocol highlights the weaknesses in the agency’s ability to access undeclared sites and carry out its mission. Officials in Damascus continue to deny that the facility was nuclear–related or that North Korea was involved.

India: Although not a signatory to the Nuclear Nonproliferation Treaty (NPT), India maintains a robust domestic nuclear energy program and actively seeks to expand it. In 2008, the United States and India sign a “123 agreement” giving India access to U.S. civilian nuclear technology. The Nuclear Suppliers Group (NSG) then lifts its ban on nuclear exports to India. The U.S.–India deal requires Delhi to open many of its civilian nuclear facilities to IAEA inspectors, which

supporters cite as an improvement from the status quo. However, the deal does not limit fissile material production or tests of nuclear weapons. Critics of the deal further argue that allowing civilian nuclear commerce with a state not party to the NPT weakens the treaty and sets a damaging precedent for the nuclear nonproliferation regime. While French and Russian companies have started projects in India, a major deterrent for U.S. companies is a new Indian liability law that permits lawsuits against suppliers of nuclear materials and plant components in the case of an accident. While the partially or fully state-owned nuclear industries in France and Russia have liability underwritten by their governments, the privately owned U.S. industry does not have such protections for international trade deals.

Iran: In February 2010, Iranian President Mahmoud Ahmadinejad announces that his country, which has been in violation of UN Security Council resolutions for years over its nuclear activities, will increase the level to which it enriches uranium from 4 percent to 20 percent, but will do so for peaceful purposes. The declaration endangers current diplomatic ententes toward Tehran and derails a proposal to send some of the country's uranium stocks to France and Russia. Turkey and Brazil revive a similar "fuel swap" agreement in May 2010, but by this time, the amount of uranium that would be transferred represents a much smaller portion of Iran's declared stocks. Iran still lacks the ability to actually fabricate nuclear fuel, which is available on the world market, further calling into question the country's intent in pursuing higher levels of enrichment. The country's continued nuclear activities bring about an additional round of sanctions from the Security Council in June 2010.

MAJOR NUCLEAR INCIDENTS

Operation Smiling Buddha, 1974 - Proliferation Risks Become Real



Using a Canadian research reactor provided through the Atoms for Peace program, India extracts plutonium and diverts it to manufacture a nuclear device similar to those tested by the United States during the Second World War. The Indian

government refers to the test as a "peaceful nuclear explosion." The event sets off an international debate over so-called dual-use technologies and leads to the formation of the Nuclear Suppliers Group (NSG). Although unknown at the time, Pakistan is also developing nuclear weapons, but uses highly enriched uranium (HEU) as the fissile material. India does not test again until 1998, when it conducts five of them and declares itself a nuclear weapon state. Pakistan has its first test in 1998.

Three Mile Island, 1979 – The Nuclear Crisis Is Born

The accident at Three Mile Island, in Pennsylvania, is the most serious in U.S.

commercial nuclear history. A mechanical failure cuts off water to one of the reactors. Ambiguous control room signals and the initial failure of plant operators to recognize the situation cause further coolant loss, seriously damaging the reactor core. The incident only leads to



minute releases of radioactivity, and no deaths or injuries result. But the accident brings about sweeping changes in emergency response planning, reactor operator training, and radiation protection. It also triggers increased public opposition to nuclear power, even though the industry was already in decline in the United States for other reasons. Following a major accident at Three Mile Island in 1979, the insurance pools associated with the Price – Anderson law are used for the first--and so far, only--time. In 2005, the U.S. Congress increases the cap amount and extends the law another twenty years. Critics of Price–Anderson argue that it provides a permanent subsidy to the nuclear industry and underestimates the risk of an accident.

Chernobyl, 1986 – Nuclear Meltdown

One of the units at the Chernobyl Nuclear Power Plant, located in the north of what is now Ukraine,



suffers a massive chain reaction during an early morning test. In a matter of seconds, the graphite reactor core overheats and turns thousands of gallons of water into pressurized steam, triggering two massive explosions. The subsequent fire spews radiation levels one hundred times as strong as the fallout from Hiroshima and blows a radioactive cloud across Europe, causing an unknown number of deaths. The world's worst nuclear disaster, it raises major concerns about Soviet nuclear power plants and causes further public opposition to nuclear power. Some areas in the exclusion zone around the plant remain off-limits to people. With the assistance of Western countries, Ukraine shuts down the fourth and final reactor at the Chernobyl site. This process started after the IAEA cited reactor design as a main cause of the accident. Eleven similar reactors, known commonly as RBMK, their Russian initials, still operate, but with modifications made after 1986. The last RBMK reactor outside Russian territory, in Lithuania, closed at the end of 2009. The Chernobyl accident attracted a great deal of interest. Because of the distrust that many people (both within and outside the USSR) had in the Soviet authorities, a great deal of debate about the situation at the site occurred in the first world during the early days of the event. Because of defective intelligence based on photographs taken from space, it was thought that unit number three had also suffered a dire accident. In Italy, the Chernobyl accident was reflected in the outcome of the 1987 referendum. As a result of that referendum, Italy began phasing out its nuclear power plants in 1988, a decision that was effectively reversed in 2008. A referendum in 2011 reiterated Italians' strong objections to nuclear power, thus abrogating the government's decision of 2008. The nuclear meltdown at Chernobyl spreads global paranoia of nuclear crises.

Fukushima Daichi Nuclear Disaster, 2011 - Challenging the Nuclear Renaissance

A massive earthquake followed by a tsunami on Japan's northeast coast (in Tohoku Prefecture) causes a power failure at the Fukushima Daiichi nuclear plant--including loss of the plant's emergency backup generators on March 11, 2011. The tsunami inundates parts of the complex and short circuits the connection from the emergency power systems to the coolant system of reactors 1,2,3 to which the power load shifted automatically following the earthquake

Without power, officials struggle to keep three of the reactor cores cool, sparking fears of a full nuclear meltdown. Following the release of some radiation-laden steam, along with hydrogen explosions authorities evacuate the area surrounding the plant, but some residents are already exposed. Sea water is then dumped to the reactor which ruins the reactor completely. As Japan tries to contain the crisis--considered the worst nuclear accident since the 1986 Chernobyl accident--the debate over the safety of nuclear power is reignited around the world. Many countries, including China, begin reevaluating the safety of their nuclear facilities, which leads Germany to take seven aging reactors offline.

PART III: DEVELOPMENT OF LEGAL INSTRUMENTS AND REGULATORY OVERSIGHT

Canada and the United States established their atomic energy governing bodies in 1946. Each of the 2 countries enacted laws governing research, development and propagation of knowledge of atomic science and the commercial construction and use of nuclear reactors to generate electricity in the 1950's. The US Congress replaces the Atomic Energy Act (1954) with the controversial Price-Anderson Act (1957) to encourage nuclear power by providing for, inter alia, a insurance system to secure adequate funds to pay claims for nuclear accidents, limited operator/owner liability etc and there by removes a barrier to private investment in nuclear power in the United States.

The "Atoms for Peace" speech culminates in the formation of the International Atomic Energy Agency (IAEA) with eighteen member countries. President Eisenhower originally envisions the IAEA as an international repository for fissile materials, but the agency instead becomes a forum for international cooperation on civilian nuclear research. Its initial role of brokering bilateral nuclear cooperation deals evolves to implementing the international nuclear safeguards regime, which the agency begins to develop in 1961.

The development of nuclear weapons by a growing number of states leads to calls for an international framework to prevent and reverse nuclear proliferation. The Nuclear Nonproliferation Treaty (NPT) opens for signature in 1968 with both U.S. and Soviet support. The core objective of the NPT is to stop the spread of nuclear weapons. The treaty also represents a compromise between states permitted to possess nuclear weapons and those without; the

former agree not to transfer them, as well as to eventually abandon them, and the latter agree not to acquire them. The controversial Article IV gives all signatory states the ability to pursue domestic nuclear power programs, but it remains unclear to what extent this applies to dual-use fuel cycle technology.

The entry into force of the NPT solidifies the role of the International Atomic Energy Agency (IAEA) in implementing nuclear safeguards, as Article III of the treaty outlines. The IAEA continues to work with its 150 member states to promote safe, secure, and peaceful nuclear technologies, and to prevent the misuse of facilities and materials intended for civil nuclear purposes. It pursues its mission through the provision of information, standards, verification, and inspections. But the IAEA also suffers from legal gaps, incomplete access, budgetary constraints, and inadequate enforcement. The Model Additional Protocol, introduced in 1997 but not yet universally applied, addresses some of these shortcomings. Events during the decades following its initial ratification and the growing role that nonstate actors come to play in nuclear proliferation, make clear the weaknesses of the NPT and IAEA.

Following India's misuse of a research reactor to make the material for a nuclear weapon tested at Pokhran, the Nuclear Suppliers Group (NSG) is formed in 1974. The NSG is a voluntary body whose participants uphold export guidelines to ensure that the technologies and materials used in civilian nuclear applications do not contribute to proliferation.

Following 3 Mile Island in 1979, Institute of Nuclear Power Operations (INPO) is set up in the United States to carry out performance and safety review checks at all nuclear plants.

The U.S.–Russia Highly Enriched Uranium Agreement establishes the framework to convert hundreds of metric tons of Russian weapons material into low-enriched uranium to fuel U.S. nuclear power plants. The agreement, commonly known as “Megatons to Megawatts,” is the first nonproliferation agreement to include a commercial component and is considered largely successful from both the security and business perspectives. The agreement will lapse in 2013, and Moscow is unwilling to renew it because it feels that it artificially depresses the price of nuclear fissile material and hopes to garner better profits through free trade in carbon regulated markets.

In 1997, the Convention on Supplemental Compensation for Nuclear Damage (CSC) opens for signature at the IAEA. The convention is an effort to bridge elements of previous international nuclear liability regimes by establishing a compensation fund that signatories pay into as well as setting time and monetary limits on compensation. Under the regime, nuclear operators are made solely liable for nuclear accidents in order to alleviate the uncertainty for international suppliers. Fourteen countries subsequently adopt the CSC, but it is not yet in force. India signs the convention in October 2010, but retains a domestic law that allows lawsuits against reactor equipment suppliers, which according to experts deviates from international legal norms like the CSC.

In 2003, an era of nuclear knowledge sharing is embarked upon with the launch of the Global Nuclear Energy Partnership (GNEP), which would assist countries in obtaining fuel for nuclear reactors without giving them access to the technology or knowledge necessary to enrich or reprocess fuel.

GNEP largely fails to achieve its objectives because of the financial costs and inertia due to a conception of limited feasibility. However, It brings to light multilateral nuclear fuel initiatives which remain under discussion as a way of supplying nuclear fuel without spreading enrichment and reprocessing technologies even today.

In the early 2000's, due in large part to concerns over greenhouse gas emissions and security of energy supply, countries around the world consider building new nuclear power plants using new types of reactors. This next generation of reactors is designed to operate at higher levels of safety and efficiency, and produce more electricity, for longer periods of time.

States seeking to start or expand their nuclear power programs increasingly sign peaceful nuclear cooperation agreements with countries such as France, Russia, and the United States. These deals establish the legal framework necessary to transfer civilian nuclear material, technology, or knowledge to a partner state, and have the potential to be profitable for the nuclear industry in the supplier country. The agreements vary in their conditions and restrictions. Some include stringent nonproliferation measures.

As concerns over proliferation of nuclear fissile material grow because of the discovery of illicit weapons development programs, the international

Critical Question:

Does your country have a nuclear sharing bilateral agreement?

community looks towards methods of assuring fuel supply without making the nuclear material vulnerable to diversion. Fuel banks are one proposed way to assure supplies of nuclear fuel, but stem the spread of domestic enrichment and reprocessing programs. In 2009, the IAEA Board of Governors approves the first such plan. Under it, Russia will stockpile 120 tons of nuclear fuel, available to any IAEA member state in good standing with its safeguards agreements. Other countries and groups have their own fuel assurance proposals, ranging from uranium reserves to the multilateral control of enrichment. All such plans face myriad economic, political, legal, and logistical challenges.

The Nuclear Nonproliferation Treaty (NPT), which gives all signatories the right to pursue peaceful nuclear programs conditional upon their agreement to forgo nuclear weapons (or eventually disarm), is reviewed every five years. The May 2010 NPT Review Conference addresses the pace of disarmament, the problem of nuclear states outside the NPT (Pakistan, India, and Israel), and strengthening the IAEA's verification powers. The conference concludes with a final document that affirms the basic goals of nuclear disarmament and nonproliferation, including language calling for states to abide by their safeguards obligations. It does not reference more robust inspections or toughened procedures to leave the treaty.

INFORMATION ON SOME KEY PLAYERS

INTERNATIONAL ORGANIZATIONS

International Atomic Energy Agency (IAEA)

The International Atomic Energy Agency was formed on 29th July 1957 after the signing of the IAEA Statute in Vienna. It is an international organization that is mandated to support, enhance and encourage the peaceful uses of nuclear technologies



and energy. It reports to the General Assembly. Although, it was initially envisioned that the IAEA would serve an international repository for fissile materials, it instead evolved into a forum for international cooperation on civilian nuclear research used to broker bilateral and multilateral treaties to ensure effective cooperation in using nuclear techniques for technology transfer. Over time the verification and security aspects of IAEA's statute gain pre-eminence and starting in 1961, it starts developing the nuclear safeguards regime to verify the claims of States vis-à-vis their nuclear programmes. It also starts conducting on site inspections and country reviews and releasing periodic reports on countries suspected of undeclared nuclear activity. The IAEA has helped shape the development of nuclear energy and ensured to a great extent the elimination of proliferation of nuclear weapons, weapons diversions etc. Based on IAEA reports, actions have been taken by the UNSC against States in violation of their obligations to the Agency (Iran, North Korea etc) . The Agency also undertakes policy formulation through the Board of Governors of 35 members , and the General Conference on 151 members apart from discharging its work through various department which aid in the scientific and technical cooperation among countries on nuclear issues.

Nuclear Suppliers Group (NSG)

The Nuclear Supplier's Group is a consortium of 46 nations to evolve safeguards and guidelines to limit and control the export and import of dual use technologies that can be applied to nuclear weapons programmes in order to prevent proliferation. It was formed in

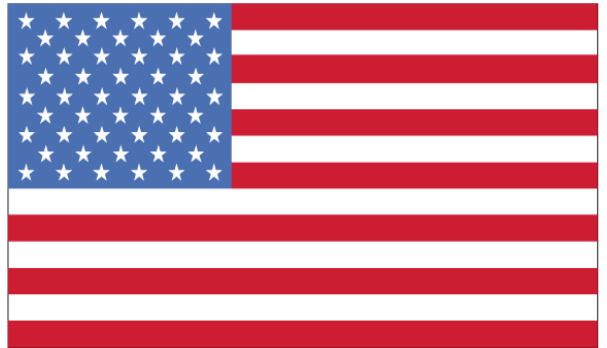
response to the 1974, India Pokhran I test which sparked fears among the Western countries of widespread nuclear proliferation. The NSG is however, now evolving into an organization whose membership is a prerequisite for commercial trade in nuclear materials, technology and knowledge for non-nuclear states . India, for example, petitioned to the NSG in 2010 to enable the 1-2-3 US-India Agreement . It was granted an exemption allowing nuclear trade with supplier countries. In 2010, US President Barrack Obama indicated to a possible revision of the conditions for membership to the NSG to accommodate India and enscript other nations as members.



KEY NATIONS

- **United States of America (USA)**

The United States of America has been at the forefront of the development of nuclear technologies, championing the nuclear agenda, cooperating with other States in the sharing of its nuclear know-how capabilities, and fissile materials. It is the single largest consumer of nuclear power with roughly 105



nuclear power stations contributing about 20% of the total energy demand. It is a country whose public policy shift has been indicative in the general sentiment of the world community at large. The Price-Anderson Act, which provides insurance pools for the owners/operators of nuclear power plants and limits their liability is meant to stimulate the construction of new nuclear power plants. Although the Obama administration has tried to push the nuclear agenda, it finds itself crippled by a lack of majority in the Senate and negative public opinion especially about the safety of nuclear installations.

In September 2009, President Barack Obama proposed UN resolution 1887, which the calls for all countries not party to the NPT to accede, as well as for greater compliance by treaty members. The administration has used the UNSC, IAEA and NPT Review Conferences to exert more pressure on Iran's nuclear program and call for more sanctions.

In April 2010, the Obama administration hosted a nuclear summit that focused on the threat of nuclear terrorism and called for greater security for nuclear materials. In addition, Obama signed a new agreement with Russia to reduce strategic weapon arsenals another 30 percent, a deal that could be used to tout U.S. progress on the NPT Article VI obligation to end the nuclear arms race. Together the countries hold 90 percent of the world's nuclear weapons.

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R u s s i a n Federation

Russia's first nuclear power plant, and the first in the world to produce electricity, was the 5 MWe Obninsk reactor, in 1954. Russia's first two commercial-scale nuclear power plants started up in 1963-64, then in 1971-73 the first of today's production models were commissioned. By the mid 1980s Russia had

25 power reactors in operation, but the nuclear industry was beset by problems. Rosenergoatom is Russia's largest utility and the only one operating nuclear power plants. Its ten nuclear plants have the status of branches. It was established in 1992 and was reconstituted as a utility in 2001.

Between the 1986 Chernobyl accident and mid 1990s, only one nuclear power station was commissioned in Russia, the 4-unit Balakovo, with unit 3 being added to Smolensk. Economic reforms following the collapse of the Soviet Union meant an acute shortage of funds for nuclear developments, and a number of projects were stalled. But by the late 1990s exports of reactors to Iran, China and India were negotiated and Russia's stalled domestic construction program was revived as far as funds allowed.

Around 2000 nuclear construction revived and Rostov-1 (also known as Volgodonsk-1), the first of the delayed units, started up in 2001, joining 21 GWe already on the grid. This greatly boosted morale in the Russian nuclear industry. It was followed by Kalinin-3 in 2004, Rostov-2 in 2010 and Kalinin 4 in 2011.

The government through the utility plans to increase capacity by 2-3 GWe every year till 2030. It must update its ageing nuclear fleet. Rosatom's long-term strategy up to 2050 involves moving to inherently safe nuclear plants using fast reactors with a closed fuel cycle. Fossil fuels for power generation are to be largely phased out.



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P e o p l e ' s Republic of



China

Most of mainland China's electricity is produced from fossil fuels (80% from coal, 2% from oil, 1% from gas) and hydropower (15%). Two large hydro projects are recent additions: Three Gorges of 18.2 GWe and Yellow River of 15.8 GWe. Rapid growth in demand has given rise to power shortages, and the reliance on fossil fuels has led to much air pollution. China therefore is looking favourably upon replacing hydro-power and coal fire plants with nuclear power stations as the mainstay of its electricity supply grid. Nuclear power has an important role, especially in the coastal areas remote from the coalfields and where the economy is developing rapidly. Generally, nuclear plants can be built close to centres of demand, whereas suitable wind and hydro sites are remote from demand.

Moves to build nuclear power commenced in 1970 and about 2005 the industry moved into a rapid development phase. Technology has been drawn from France, Canada and Russia, with local development based largely on the French element. By around 2040, PWRs are expected to level off at 200 GWe and fast reactors progressively increase from 2020 to at least 200 GWe by 2050 and 1400 GWe by 2100.

Prior to 2008, the government had planned to increase nuclear generating capacity to 40 GWe by 2020 (out of a total 1000 GWe planned), with a further 18 GWe nuclear being under construction then. However, government targets for nuclear power have been increasing. As of June 2010, official installed nuclear capacity projections were 70–80 GWe by 2020, 200 GWe by 2030 and 400–500 GWe by 2050. Following the Fukushima accident and consequent pause in approvals for new plants, the target is now more like 60–70 GWe by 2020.

In December 2011 the National Energy Administration (NEA) said that China will make nuclear energy the foundation of its power-generation system in the next "10 to 20 years", adding as much as 300 GWe of nuclear capacity over that period. Two weeks earlier the NDRC vice-director said that China would not swerve from its goal of greater reliance on nuclear power. The former head of the NEA said that full-scale construction of nuclear plants would resume in March 2012.

In September 2010, the China Daily reported that China National Nuclear Corporation (CNNC) alone planned to invest CNY 800 billion (\$120 billion) into

nuclear energy projects by 2020. Total investment in nuclear power plants, in which CNNC will hold controlling stakes, will reach CNY 500 billion (\$75 billion) by 2015, resulting in 40 GWe on line, according to CNNC. In order to fund the company's expansion target, CNNC planned to list its subsidiary, CNNC Nuclear Power Co Ltd in 2011, to attract strategic investors.

China is rapidly becoming self-sufficient in reactor design and construction, as well as other aspects of the fuel cycle. But currently, it imports reactor designs and construction from Russia, the USA and France.

- **France**

France derives over 75% of its electricity from nuclear energy. This is due to a long-standing policy based on energy independence. France is the world's largest net exporter of electricity due to its very low cost of generation and gains over EUR 3 billion per year from this. France has been very active in developing nuclear technology.



Reactors and fuel products and services are a major export. It is building its first Generation III reactor and planning a second. About 17% of France's electricity is from recycled nuclear fuel.

The present situation is due to the French government deciding in 1974, just after the first oil shock, to expand rapidly the country's nuclear power capacity. This decision was taken in the context of France having substantial heavy engineering expertise but few indigenous energy resources. Nuclear energy, with the fuel cost being a relatively small part of the overall cost, made good sense in minimizing imports and achieving greater energy security.

As a result of the 1974 decision, France now claims a substantial level of energy independence and almost the lowest cost electricity in Europe. It also has an extremely low level of CO₂ emissions per capita from electricity generation, since over 90% of its electricity is nuclear or hydro.

In mid 2010 a regular energy review of France by the International Energy Agency urged the country increasingly to take a strategic role as provider of low-cost, low-carbon base-load power for the whole of Europe rather than to concentrate on the energy independence which had driven policy since 1973.

France is now opening up its commercial nuclear industry through State-owned Areva, which is constructing nuclear reactors for countries, including India and China, around the world.

- **Kazakhstan**

Kazakhstan has 15% of the world's uranium resources and an expanding mining sector, expecting over 19,000 tonnes Uranium (tU) annual production in 2011, planning for further increase to 2018. In 2009 it became the world's leading uranium producer, with almost 28% of world production, and then 33% in 2010. A single nuclear power reactor operated from 1972 to 1999, generating



electricity and for desalination. The government is committed to increased uranium exports, and is considering future options for nuclear power.

Kazakhstan has no national electricity grid, but a northern grid links to Russia and a southern one links to Kyrgyzstan and Uzbekistan. Electricity consumption is 48 TWh/year, from 17 GWe of plant, mostly fossil fuel fired and now privatized.

Kazatomprom is the national atomic company set up in 1997 and owned by the government. It controls all uranium exploration and mining as well as other nuclear-related activities, including imports and exports of nuclear materials. It announced in 2008 that it aims to supply 30% of the world uranium by 2015, and through joint ventures: 12% of uranium conversion market, 6% of enrichment, and 30% of the fuel fabrication market by then. Kazakh plans for future nuclear power include large light-water reactors for the southern region, 300 MWe class units for the western part and smaller cogeneration units in regional cities. There are proposals for a new nuclear power plant near Lake Balkhash in the south of the country near Almaty.

- **India**

India has a flourishing and largely indigenous nuclear power program and



expects to have 20,000 MWe nuclear capacities on line by 2020 and 63,000 MWe by 2032. It aims to supply 25% of electricity from nuclear power by 2050. Because India is outside the Nuclear Non-Proliferation Treaty due to its weapons program, it was for 34 years largely excluded from trade in nuclear plant or materials, which has hampered its development of civil nuclear energy until 2009. Due to these trade bans and lack of indigenous uranium, India has uniquely been developing a nuclear fuel cycle to exploit its reserves of thorium. Now, foreign technology and fuel are expected to boost India's nuclear power plants considerably. All plants will have high indigenous engineering content. India has a vision of becoming a world leader in nuclear technology due to its expertise in fast reactors and thorium fuel cycle.

Current Situation

Nuclear technology uses the energy released by splitting the atoms of certain elements. It was first developed in the 1940s, and during the Second World War research initially focussed on producing bombs by splitting the atoms of either uranium or plutonium.

In the 1950s attention turned to the peaceful purposes of nuclear fission, notably for power generation. Today, the world produces as much electricity from nuclear energy as it did from all sources combined in 1960. Civil nuclear power can now boast over 14,000 reactor years of

Nuclear Energy Factsheet

- **The first commercial nuclear power stations started operation in the 1950s.**
- **There are now over 440 commercial nuclear power reactors operating in 30 countries, with 377,000 MWe of total capacity.**
- **They provide about 14% of the world's electricity as continuous, reliable base-load power, and their efficiency is increasing.**

experience and supplies almost 14% of global electricity needs, from reactors in 30 countries.

In fact, many more than 30 countries use nuclear-generated power.

Many countries have also built research reactors to provide a source of neutron beams for scientific research and the production of medical and industrial isotopes.

Today, only eight countries are known to have a nuclear weapons capability. By contrast, 56 operate civil research reactors, and 30 host some 440 commercial nuclear power reactors with a total installed capacity of over 377,000 MWe (see

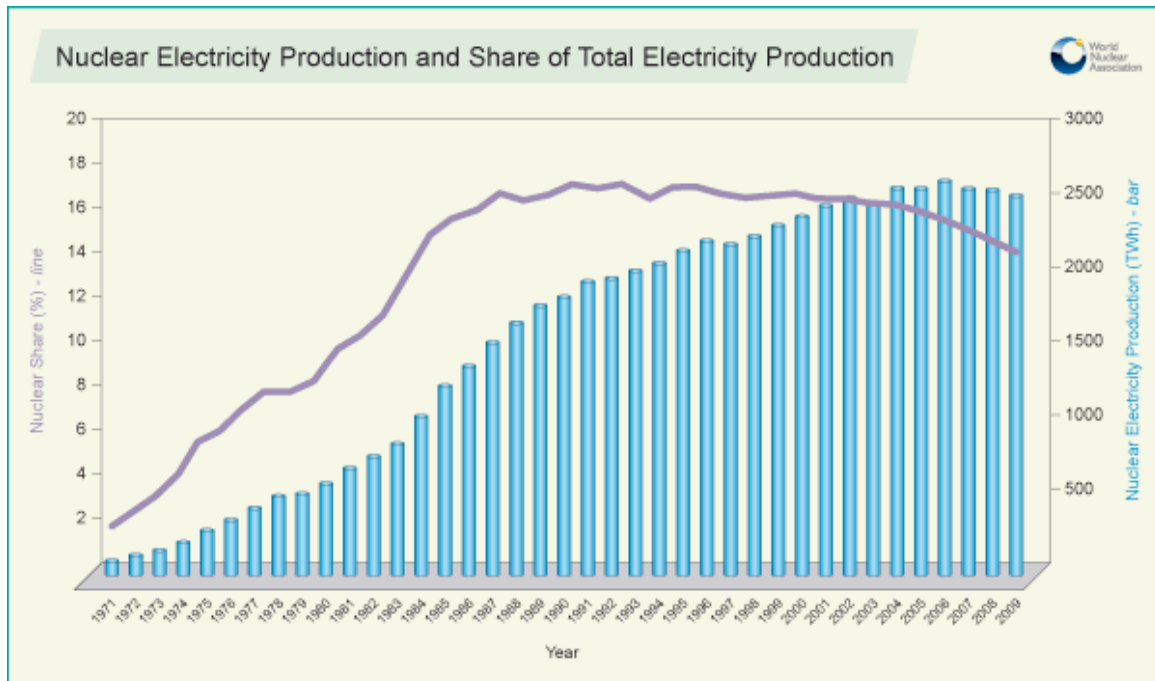


table). This is more than three times the total generating capacity of France or Germany from all sources. Over 60 further nuclear power reactors are under construction, equivalent to 17% of existing capacity, while over 150 are firmly planned, and equivalent to 46% of present capacity.

Sixteen countries depend on nuclear power for at least a quarter of their electricity. France gets around three quarters of its power from nuclear energy, while Belgium, Bulgaria, Czech Republic, Hungary, Slovakia, South Korea, Sweden, Switzerland, Slovenia and Ukraine get one third or more. Japan, Germany and Finland get more than a quarter of their power from nuclear energy, while in the USA one fifth is from nuclear. Among countries which do not host nuclear power plants, Italy gets about 10% of its power from nuclear, and Denmark about 8%.

Following the Fukushima Daichi nuclear power incident in Japan, countries have begun to reassess their planned expansion of nuclear power programs.

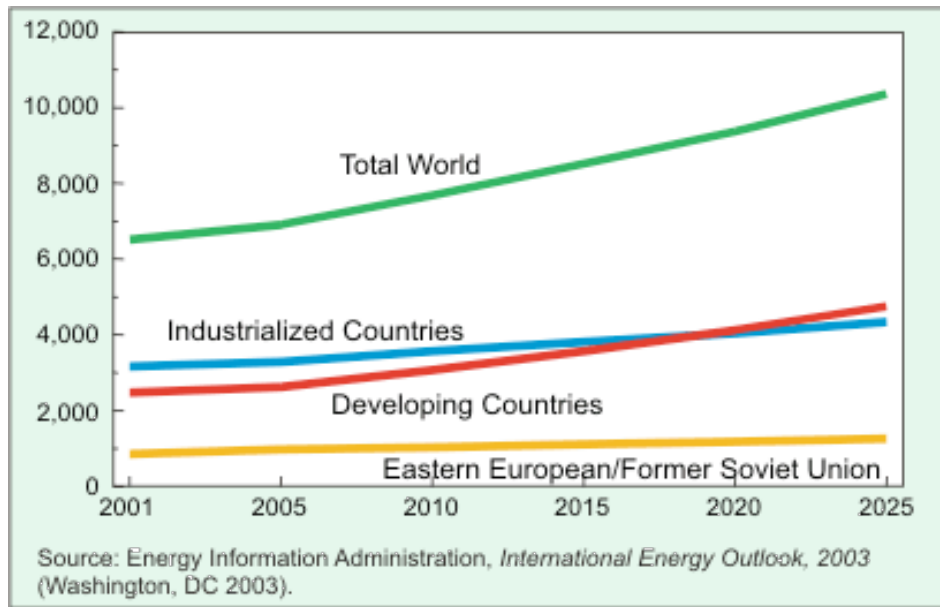
Challenges

1/ GREENHOUSE GASES EMISSIONS

The Earth's history has been recording natural variability and fluctuations of the climate throughout its course. However, never before has it seen such a sinisterly steep rise in the concentration of greenhouse gases (the most prevalent greenhouse gas is carbon dioxide CO₂) caused mainly by multifarious human activities. Reducing atmospheric GHG concentrations have become an international priority as evidenced by the signing of the Kyoto Protocol.

During the past 20 years, about three-quarters of human-made carbon dioxide emissions were from the burning of fossil fuels for energy. Since around 150 years ago when large-scale industrialization started, levels of several important greenhouse gases have increased by about 25 percent.

The world's carbon dioxide emissions are expected to increase by 1.9 percent annually between 2001 and 2025. Much of the increase in these emissions would most probably in the developing nations such as China and India with emerging economies in tremendous need of fossil energy.



World Carbon Dioxide Emissions by Region, 2001–2025

The warming of the Earth over the last half-century due to GHG has led to undesired negative environmental impacts such as the melting of glaciers in polar regions, extreme weather conditions like hurricanes, tornadoes, floods, droughts, and changes in the flowering patterns of plants and breeding patterns of animals. These all adversely affect human life, resulting in increased poverty, water scarcity, and food insecurity.

With the steadily and inexorably increasing demand for energy for economic growth and human daily consumption, indubitably there is an urgency to manage the energy sector's contribute to global GHG emissions by decarbonising energy supply, which requires a reduction in the heavy reliance on fossil fuels. Nuclear power is perceived widely as the single most significant means of limiting the increase in GHG concentrations in the power generation sector, while enabling access to abundant electricity at a stable and low cost. Unlike the combustion of fossil fuels, the process of nuclear fission does not emit any CO₂ or other GHGs. Hence, the current use of nuclear energy which accounts for about 15% of the world's electricity generation, avoids the emission of about 2.1 billion tonnes of CO₂ eq every year.

2/ CARBON NEUTRALITY

Although nuclear fission itself generates no CO₂, some CO₂ emissions arise from many steps of the nuclear fuel cycle which require the use of fossil fuel-based energy source, such as the construction of the plant, the mining of the Uranium, the enrichment of the Uranium, its conversion into Nuclear Fuel, its final disposal and the final plant decommissioning. The amount of CO₂ generated by these secondary processes mostly depends on the method used to enrich the Uranium (for example, the gaseous diffusion enrichment process uses about 50 times more electricity than the gaseous centrifuge method) and the source of electricity used for the enrichment process. The potential to reduce indirect emissions is also dependent on the availability of sources of higher grade uranium which requires less enrichment. This has been the subject of some controversy as the production of nuclear energy is not carbon neutral.

3/ RATE OF EXPANSION

The contribution that nuclear power will actually make to reducing carbon emissions over the next few decades depends upon how rapidly it can be scaled up, and recent history is sobering. Given the urgency to reduce GHG emissions, critics have been arguing that to meet to required expansion of nuclear power to replace fossil fuel electricity generation would take far too long. The existing global fleet of 436 commercial nuclear power reactors, with a total net installed capacity of about 370 GWe, provides about 15 percent of the world's supply of electricity today. For nuclear energy to be a "game changer" in bringing emissions down to low levels, nuclear energy would need to be the key backbone for the electrical grid to:

- power homes, businesses, and factories so that the economic growth prospects for both the developed and developing world are robust;
- provide the electricity for plugin hybrids and all other electric vehicles as a replacement for fossil fuels;
- and enable the production of clean water, hydrogen, and other byproducts such as process heat for large manufacturing operations.

However, it has taken about 40 years for the nuclear industry to reach this level, hence in the future the rate of expansion will need to be much faster if nuclear is to play a significant role in reducing carbon emissions. CO₂ emissions are expected to reach about 41 gigatons (GT) per year (that is, 45 percent above

today's level) by 2030 and perhaps 45–50 GT (60–80 percent above today's level) by 2050. If new nuclear power plants were called upon to eliminate, say, 25 percent of the increase in CO₂ emissions, roughly 700–900 GWe of new nuclear capacity would have to be added by 2050. In other words, in order to achieve the goal of displacing one quarter of the projected increase in carbon emissions, at least twice as much nuclear capacity would have to be built in the next 40 years as was built in the last 40. Furthermore, since many existing nuclear plants will reach the end of their useful life during this period and will have to be replaced, the actual requirement would triple. Historical evidence of the development of nuclear energy suggests that this scenario is unrealistic, and there is also the matter of mobilizing industrial, human and financial resources on considerable strength to facilitate such a large scale expansion, especially in developing nations.

4/ COSTS AND RETURNS

Nuclear energy is one of the most expensive forms of energy, with true costs hidden underneath subsidies, limits on liability for accidents, and the omission of the costs for waste storage and nuclear power plant decommissioning. Moreover, the prospect of building 1000 new clear plants by 2050 to reduce about 25 percent of the increase in CO₂ emissions is highly optimistic. It is argued that investing the same amount of resources into alternative sustainable energy sources such as wind and solar power could possibly yield better energy returns.

5/ ENVIRONMENTAL RISKS

The most major risk from nuclear energy would probably be the possibility of a failure in a nuclear reactor which results in massive radioactive release that have serious and far-reaching impacts on health, ecosystems, social and economic systems, as evidenced in the Three Mile Island (1979) and Chernobyl (1986) accidents with grievous consequences. In spite of an existing low possibility for such a reactor accident, the expansion of nuclear power generation would magnify the risk of a reactor accident. The fact that nuclear

technology is yet fully developed also mean unforeseen complications and leaves some doubts on the reliability of nuclear energy. Safety improvements are hence constantly being developed with existing measure being fine-tuned, but the impacts of these on investments and operational costs would be another head-spinning problem. The Germany government shut down the seven oldest nuclear power plants within a few days following the Fukushima event, and has decided to keep these facilities closed permanently while it is accelerating the plans to phase out all of its remaining nuclear power plants stepwise by 2022. Nuclear power accounts for approximately a quarter of electricity generated in Germany, and the impact of Germany's decision to phase-out nuclear by 2022 is going to affect the energy system in Europe, as more electricity will be traded across borders and as gas-powered plants are expected to be brought online to balance the system.

6/ PROLIFERATION AND SECURITY CONCERNS

The security risk of the spread of nuclear weapons, fissile material, and weapons-applicable nuclear technology and information to nations which are not recognized as "Nuclear Weapon States" by the Treaty on the Nonproliferation of Nuclear Weapons raises up the stake for nuclear energy. Nuclear plants are also potential targets for terrorist attacks since nuclear energy is coupled to nuclear weapons as the same fuel cycle used for nuclear power generation is also used for nuclear weapons production. Stockpiling of fissile materials could result in a diversion for military purposes. Uranium and plutonium, also called fissile materials, are two main materials used to produce nuclear energy as well as weapons. Uranium occurs naturally, while plutonium is produced as a by-product in nuclear power reactors. This dual-nature of uranium for both peaceful and military purposes is a major proliferation problem associated with the nuclear fuel cycle. While the majority of the countries do not pose a proliferation concern, they do possess the technical capabilities to divert fissile materials for the production of nuclear weapons. To prevent the spread of nuclear weapons and weapon technology, to promote cooperation in the peaceful use of nuclear energy, and to achieve nuclear disarmament, the Nuclear Non-proliferation Treaty (NPT) came into force on March 5th, 1970 as an international treaty of indefinite duration. The NPT separated between two categories of states: nuclear weapon states (NWS) which

are the United States of America, Russian Federation, the United Kingdom, France Republic and People's Republic of China, and non-nuclear weapons states (NNWS). Each NNWS NPT member state has to enter into a safeguards agreement with the International Atomic Energy Agency (IAEA) that requires the state to declare its nuclear facilities and activities. IAEA inspectors verify these declarations through on-site inspections in the host country. One of the limitations to these safeguards activities is that they only apply to NNWS. All five NWA own full nuclear fuel cycle and only abide to voluntary safeguards agreements in which they promise to move toward to gradual reduction in their arsenals of nuclear weapons with the ultimate goal of complete nuclear disarmament. As of July 2008, there are 189 states party to the treaty. Four other states who are non-parties to the treaty have also acquired, or are presumed to have acquired, nuclear weapons. These are India, Pakistan, Israel and North Korea who was a party to the NPT but withdrew in 2003. Recent international tension over Iran's desire to develop a nuclear energy programme has further raised concerns over states using nuclear energy production as a front to develop the capability to produce nuclear weapons. Many history and military experts believe that proliferation can be slowed, but never stopped, for technology can never be uninvented, and it is a dangerous nature of human to want the ultimate weapon of mass destruction to exercise political and military power.

7/ SUPPLIES OF NUCLEAR FUEL

Worldwide, at the beginning of 2007, there were 435 nuclear power reactors in operation, totalling 367 GWe of generating capacity. The expansion of nuclear power production to 1000 new nuclear energy plants in 2050 would require a parallel increase in fuel cycle capacities. Long-term uranium fuel supply is another area of uncertainty of nuclear power's future. Present reserves amount to 3.5 million tonnes and given the rate of usage at the status quo of approximately 67,000 tonnes a year, these reserves are projected to last for just over 50 years. With the decreasing supply of uranium, the price of its ore is likely to be pushed up, heavily putting a strain on the economic efficiency of nuclear energy production. Furthermore, the issue of uranium scarcity adds a further level of obstacles with regard to environmental concerns over uranium exploration and mining, required time periods to discover and develop sources

of uranium ore and also the development of refinement capacity in tandem. The latter poses difficulties since refinement technology is sensitive and concerns over its impact on international security could prove to be an effective barrier to its spread. However, The latest edition of the Red Book, the authoritative biennial report produced jointly by the Nuclear Energy Agency of the OECD and the International Atomic Energy Agency, estimates that the identified amount of conventional uranium resources that can be mined for less than \$130 per kilogram is 5.5 million tons, but world uranium resources in total are expected to be much higher. Based on geological evidence and knowledge of unconventional resources of uranium, such as phosphates, the Red Book considers that more than 35 million metric tons will be available for exploitation. Given that in the entire 60-year history of the nuclear era, the total amount of uranium that has been produced adds up to about 2.2 million metric tons, the availability of uranium is evidently not a limiting factor at this stage of nuclear power development. Nevertheless, the situation from now till the end of the century may be tumultuous, and measures to secure a reliable long-term supply of uranium for the production of nuclear power need considering and contemplating.

8/ WASTE DISPOSAL

Nuclear power, on the one hand, is reliable and environmentally friendly, but very dangerous on the other hand. It must be sealed up and buried for many thousands of years to allow the radioactivity to die away during which it must be kept safe from natural disasters and human destructive activities. Although the fuel for nuclear power, uranium, is relatively inexpensive at the moment, it requires larger capital cost because of emergency, containment, and radioactive waste and storage systems. Although temporary disposal technologies for radioactive waste – a fatal environmental hazard, have been well-developed and utilized in nations possessing nuclear technology, the problem of final disposal of nuclear waste remains. No permanent solution to this problem exists at present, and an expansion of nuclear energy production would only exacerbate the pressure on existing waste disposal facilities, waste disposal sites, as well as the search for a solution to final disposal.

Suggested Solutions

The expansion of existing programmes such as International Expert Group on Nuclear Liability (INLEX) to include research on ways to improve on safety and waste disposal methods of nuclear power is strongly encouraged. Also, there is an urgency to draft out a new set of general guidelines such as the determining of zones that are seismically safe for member states to follow and a new set of guidelines that nuclear plant operators should follow to reduce human-induced errors in view of recent events.

There have been suggested methods by the experts to deal with potential uranium constraints. Firstly, closing the fuel cycle can help to achieve very high burn-up (more than 90 percent). Secondly, embarking on an aggressive program is essential to improve the ability to locate and recover uranium resources economically. A life-cycle economic analysis for waste disposal will be needed to determine the efficacy of closing the fuel cycle at that time. If closing the fuel cycle is economically sensible, then any fuel supply problems will be solved as a by-product. A potential backstop for both options is the recovery of uranium from seawater. Currently, only Japan is pursuing this option in a significant way, and Japanese researchers are advertising a present-day recovery cost of \$1,000 per kilogram. That is an order of magnitude more expensive than standard uranium production costs, but the Japanese experience suggests that an eventual goal of \$150 per kilogram may be achievable.

Developed nations with high level security facilities are further encouraged to contribute these facilities as intermediate repositories for the storage of nuclear waste prior to the discovery of new technology to dispose such waste.

All member states of the Nuclear Non-Proliferation Treaty should strictly refrain from sharing information pertaining to the development of nuclear capability, as well as the building of nuclear plants with states that have arms sanctions imposed by the United Nations Security Council due to misuse of nuclear technology.

International and regional organizations such as World Bank or Asian Development Bank should consider supporting the development of nuclear

energy in less economically developed countries with low-interest loans provided that the countries meet the requirements for the construction and technologies to run nuclear plants.

Nations are to be reminded that nuclear power plants cannot be built quickly enough and in a safe, secure manner to be a major global solution for future energy shortage and climate change. Instead of heavy dependence on nuclear energy, research and development on alternative renewable energy sources such as hydro-energy, solar energy, wind energy and biomass energy to minimize destructive and damaging impacts on the environment, is a wiser and more far-sighted policy. For example, Latin America already has a long tradition of utilising renewable energy sources like large-scale hydropower, biofuels and biomass; hydropower capacity in Latin America is 20 per cent of the global installed capacity. Brazil boasts up to 350GW wind potential at 100 metre hub height; for comparison, global installed wind power capacity at the end of 2010 was 197GW. Mexico could have 11GW of wind potential with an above-30 per cent capacity factor; and Argentina's wind resources could "supply Latin America's entire electricity demand several times over" according to GWEC, the Global Wind Energy Council. Wind adds to the existing portfolio of renewables and helps offset some of the challenges that climate change-related changes in weather patterns can mean for hydropower and other renewables. Another outstanding example to validate for the potential of renewables would be Korea's first concentrating solar power (CSP) project, which launched in June 2011 in Daegu, South Korea. It is situated on a 20,300m² area with 450 heliostats two metres in diameter, which reflect solar heat and a 50m tower equipped with a solar heat absorber and a 200kW power generator. Initiated by the Korean government, private sector participants were led by Daseung Group.

Timeline of Events:

- 1923 – Formation of the World Energy Council
- 1951 – Generation of power by nuclear reactor achieved
- 1953 – Eisenhower’s “Atoms for Peace” speech
- 1955: First International Conference on the Peaceful Use of Nuclear Energy held in Geneva, Switzerland by the UN
- 1957: Formation of the International Atomic Energy Agency
- 1970 – Nuclear Non-Proliferation Treaty
- 1974 – Operation Smiling Buddha – Proliferation Risks Become Real
- 1979 – Three Mile Island accident
- 1986 – Chernobyl accident
- 1992 – United Nations Framework Convention on Climate Change signed by 154 states at Earth Summit in Brazil
- 1997 – Kyoto Protocol with legally binding emissions cuts for industrialized states
- 2005 – Kyoto Protocol comes into effect
- 2011 – Nuclear accidents in four power plants in Japan occur following the Tohoku earthquake and tsunami.

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