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Contemporary Perspectives on Nuclear Proliferation

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Perspectives on Nuclear Proliferation[1]

ABSTRACT

Although prospects of a nuclear renaissance have been weakened by the Fukushima disaster of March 2011, the nuclear energy industry is still set to expand over the coming decades, primarily driven by significant growth in demand for energy and the ability of nuclear power to provide clean and somewhat green electricity. Inherent in the expansion of nuclear power is increased pressure on the non-proliferation regime, which is notably threatened at present with Iran's nuclear ambitions. Since the dramatic entry of nuclear power into international relations in 1945, the proliferation of nuclear weapons has been a major issue in global security as well as a dominant force in the foreign policies of nuclear weapon possessors and aspirants alike.

Non-proliferation measures, beginning with the Nuclear Non-proliferation Treaty of 1968, have been developed via numerous international institutions and a complex web of multilateral and bilateral agreements, and together form the non-proliferation regime. Although four states remain non-signatories, only three new states have acquired nuclear weapons since the Treaty came into force. There is still no consensus regarding what motivates states to develop nuclear programs and build bombs. In this study a comprehensive review of the literature on nuclear proliferation is presented. These concepts are then discussed, linking theory and experience. The current state of nuclear apartheid, whereby nuclear weapon possession has been institutionalised, places a great deal of pressure on the non-proliferation regime. Although problems may exist in the regime, the proliferation of nuclear weapons has been far less extensive than many have forecast.

1 I would like to thank Associate Professor Phil Simmons, University of New England, for the idea as well as help and guidance along the way in writing this paper.

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List of Acronyms

CEA	Commissariat à l'énergie
CTBT	Comprehensive test ban treaty
DPRK	Democratic People's Republic of Korea
GWe	Gigawatt electrical
GWh	Gigawatt hour
HEU	Highly enriched uranium
IAEA	International Atomic Energy Agency
IEA	International Energy Agency
INES	International Nuclear and Radiological Event Scale
kWh	Kilowatt hour
LEU	Low enriched uranium
LCOE	Levelised cost of electricity
MAD	Mutually Assured Destruction
Mtoe	Million tonnes of oil equivalent
NATO	North Atlantic Treaty Organisation
NNWS	Non-Nuclear Weapons State
NPT	Nuclear Non-proliferation Treaty
NSG	Nuclear Suppliers Group
NWFZ	Nuclear Weapon Free Zone
NWS	Nuclear Weapon State
OECD	Organisation for Economic Co-operation and Development
SQ	Significant quantity (of fissionable material)
UN	United Nations
UNSC	United Nations Security Council
WANO	World Association of Nuclear Operators
WEO	World Energy Outlook
WNA	World Nuclear Association

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Introduction

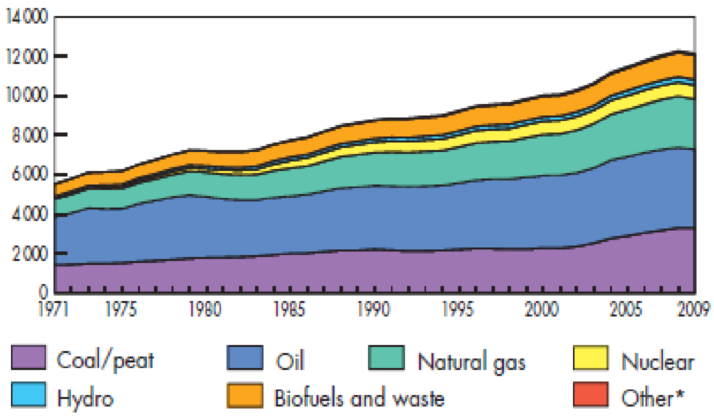
The nuclear energy debate is as contentious now as it ever has been in not only Australia, but right around the world. As Japan grapples with the aftermath of a nuclear disaster, politicians at home argue as to whether or not Australian uranium should be sold to the nuclear armed India for use in civilian power facilities. Next door to India, Pakistan spawns an arms race. Iran's nuclear intentions are closely monitored from all angles, with Israel contemplating a pre-emptive strike as it has done previously against both Iraq and Syria. Despite having oil aplenty, the United Arab Emirates chooses to invest in nuclear power. Decisions to invest in nuclear energy at a country level are complex decisions, involving huge capital costs and heavy burdens of safeguards and security measures. In addition, the issue of nuclear proliferation remains as real today as it ever has been, making nuclear investment decisions significant in the field of international relations.

Drivers of a growing nuclear energy industry

The world has a seemingly insatiable appetite for energy. Global primary energy supplies have been growing rapidly since the industrial revolution, and as shown in Figure 1, have almost doubled from 1971 to 2009.

Figure 1 **World total primary energy supply from 1971 to 2009 by fuel (Mtoe)**

Source: IEA 2011 Key World Energy Statistics



Primary energy is estimated by the International Energy Agency (IEA) to grow by 40% between 2009 and 2035. Of this, the demand for electricity is expected to increase from 16,429TWh in 2007 to 28,930TWh by 2030[2] representing stronger global growth than any other form of primary energy.3 While fossil fuels are poised to provide for much of this increase, pressure to address climate change is mounting. Although the reductions laid out by the Kyoto Protocol seem unlikely to be achieved, particularly if a significant emitter such as the United States fails to ratify the Protocol, there is

[2] OECD/IEA World Energy Outlook 2009 pg 96.
[3] OECD/IEA World Energy Outlook 2010 executive summary.

mounting universal pressure on energy producers to lower their carbon emissions and makes climate change a factor in state planning of energy investments.

Nuclear power has the potential to play a pivotal role in meeting such demands. Nuclear electricity generation results in a huge amount less carbon per kWh than that generated by coal (see Appendix A), which is currently the dominate source of fuel for power stations. In terms of low-carbon electricity production, nuclear power is comparable with wind generated electricity. Prior to the Fukushima accident in March 2011, the world had been abuzz with talk of a 'nuclear renaissance'. Indeed, the industry is still set to expand with over sixty reactors under construction in fourteen countries and 150 planned across the globe over the next ten years.[4] The World Nuclear Association (WNA 2011) estimates that nuclear power capacity will increase from 367GWe in 2008 to somewhere between 1140 and 3688GWe by 2060.

The WNA points to a number of drivers for a nuclear renaissance. Global increase in energy demand has already been mentioned, and with electricity consumption set to double from 2007 to 2030 nuclear power production is an effective way of increasing base-load supply. Energy security has been a major issue on the global political stage, with vulnerabilities highlighted by interruptions to coal and gas supplies causing states to seek to reduce their reliance on these sources. Uranium is widely available, and a year or two's supply of nuclear fuel can be stored inexpensively and with relative ease. Climate change has also been mentioned, and nuclear power is currently the only available large scale, low-carbon alternative to fossil fuels.[5] Economics obviously plays a role in any large investment decision; as the carbon market develops and emission targets place upward pressure on carbon prices the economic advantage of nuclear power will increase. Nuclear power is also much less exposed to commodity market volatility as the most significant cost is the capital outlay of the plant itself.[6]

Improvements in nuclear technology have seen a steady increase in efficiency and, prior to Fukushima, safety. Current reactors have enjoyed efficiency improvements, while new generation reactor technology promises to further these with the addition of improved heat utilisation and increased lifespan. On the technical horizon, fast neutron and breeder reactors have the potential to close the fuel cycle with an endless supply of fuel and very little in the way of waste[7].

Findlay (2011, p26-31) points out two drivers which are not mentioned so often in the nuclear renaissance material. The first is political drivers in countries without nuclear energy: "the quest for national prestige; a perceived need to demonstrate a country's prowess in all fields of science and technology; a predisposition towards high-profile, large scale projects of the type that nuclear represents; and the desire for modern, cutting edge technology no matter how suited or ill-suited to an individual country's requirements" (p26). The notion of 'nuclear hedging' is mentioned here too, whereby a nation engages with nuclear technology for peaceful purposes, but with the intention

[4] WNA 2011 http://www.world-nuclear.org/info/inf17.html
[5] Renewables do not currently have the capacity to provide reliable and cost effective base load demand.
[6] As opposed to coal powered plants which are relatively cheap to build and expensive to run. For a more detailed comparison of the costs electricity generating methods see Appendix B.
[7] For a more detailed explanation of this see Findlay 2011.

of keeping the nuclear weapon option open and more available. Secondly, he claims that promotional drivers contribute to the nuclear revival. Countries with nuclear technology and material can generate export revenue through sales and related services. This has been the case for France, Russia and the US and indeed has contributed significantly to the expansion of the industry. Moreover, nuclear promotion at domestic levels has further revived the energy as public support has increased.

India and China have been at the forefront of the expansion of the nuclear energy industry, with some 30 reactors under construction in China and India planning to construct 20 to 30 new reactors by 2020[8]. With these rapidly growing economies seeking to lift millions of people out of poverty, reliable, clean and affordable electricity is a major issue on their agendas. Similarly, many other developing countries see nuclear as a way of meeting their energy needs, keeping the other factors mentioned in mind.

Nuclear energy is not without its drawbacks however: the "dauntingly expensive" (Findlay, 2011 p34) price tag of a nuclear power plant, issues relating to the fuel cycle, industry bottlenecks and carbon economics can all be obstacles on the road to nuclear power[9]. There are a number of very significant risks involved with nuclear power, too, which warrant further discussion.

The risks of nuclear energy

The nuclear fuel cycle

The nuclear fuel cycle begins with the discovery of uranium deposits in rock, usually in the form of uranium oxide U3O8, also known as yellowcake. In preparation for use as fuel in a nuclear reactor, this uranium must first be converted into uranium hexafluoride and then enriched to a state whereby a nuclear chain reaction will occur, which is also referred to as reaching criticality. Uranium deposits largely consist of two isotopes, U-235 and U-238 which differ only in the number of neutrons held in the nucleus; however it is the lighter U-235 isotope which is required in the fission process resulting in nuclear energy. Most reactors use lowly enriched uranium (LEU), which requires the fuel be enriched from 0.7% U-235 in its natural state to some 3-5% U-235. This enrichment process can occur either by gaseous diffusion or by centrifuge, and requires substantial facilities to do so. This is referred to as the front end of the fuel cycle and presents a relatively low level of risk, although ranges from mining right through to enrichment.

The enriched uranium fuel is usually pelletised and encased in metal tubes. These tubes can then be arranged in fuel assemblies in the reactor itself. In the reactor nuclear fission occurs, whereby atoms split releasing energy in the form of heat, which is then used to heat water to make steam which then drives turbines which produce electricity. The reactor core requires a moderator (usually water, but can also be heavy water or graphite) to slow down the neutrons released in the fission process to ensure

[8] http://www.world-nuclear.org/info/inf104.html

[9] See Appendix C for a more thorough discussion.

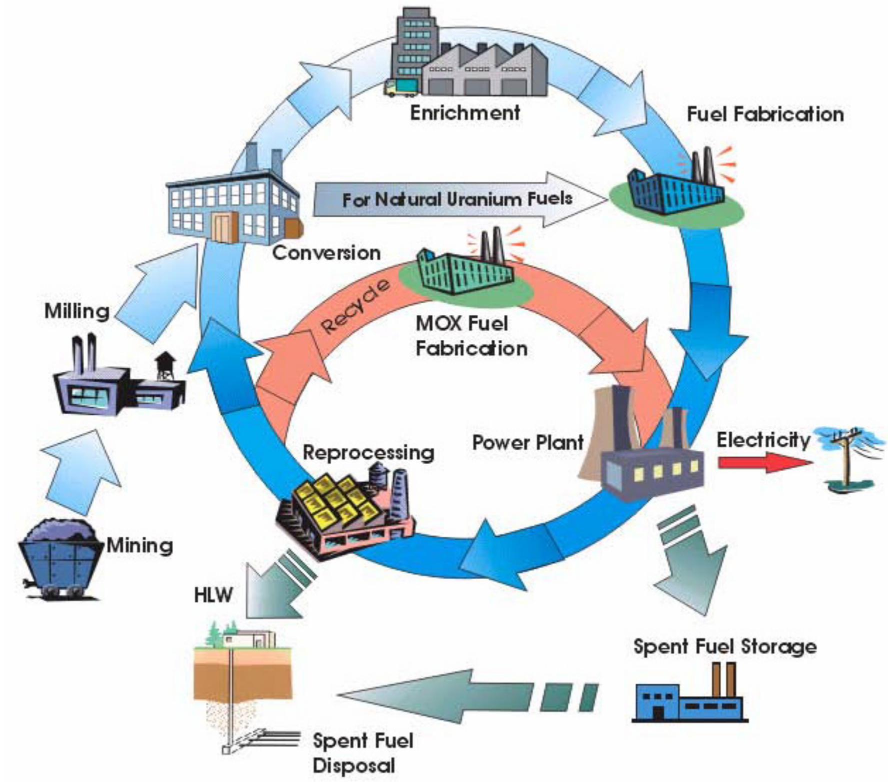
a chain reaction, and control rods made of neutron-absorbing material (such as cadmium, hafnium or boron) are used to control the rate of the reaction by absorbing neutrons. Heat is transferred from the core via a coolant (liquid or gas) which then generates steam for use through the turbine. Due to the radioactive nature of the core, it is encased in a containment structure which is typically a metre-thick concrete and steel construction. The risks of a nuclear reactor are perhaps the most publicised due to the disastrous consequences of a meltdown, as occurred at Three Mile Island, Chernobyl and Fukushima.

Nuclear fuel is removed from a reactor after 12-24 months in use as the nuclear reaction become inefficient due to neutron absorption. The 'spent' nuclear fuel still contains fissionable material. This means that it is both radioactive and heat producing and also that further use is possible should the fuel be reprocessed and re-enriched. Spent fuel is usually transferred into a storage pond in which water shields the radiation and absorbs heat. The longer the fuel is stored the lower the level of radioactivity therefore making it safer to handle and store elsewhere.

Alternatively, spent fuel can be stored in specially engineered dry facilities which are air cooled. Both methods of storage are, however, only an interim step before the fuel is either reprocessed or disposed of.

Figure 2. The typical nuclear fuel cycle

Source: IAEA-TECDOC-1613. Nuclear Fuel Cycle Information System



This represents the back end of the fuel cycle and presents some potentially very serious problems. The nuclear fuel cycle is illustrated in Figure 2.

Reactor risk

The recent Fukushima disaster has put reactor risk once again at the forefront of nuclear resistance, more pertinent now than ever. As Japan struggled to deal with radiation leaking out of the damaged Tokyo Electric Power Company (Tepco) reactors the world looked on in angst, making constant updates to the estimated damage toll; socially, economically and environmentally. Now, fourteen months after the accident, vast areas surrounding the plant remain evacuated with the clean-up years from completion. Only a month prior to the accident, supporters of nuclear energy across the globe saw the Chernobyl disaster of 1986 as a distant dent in the glimmering future of nuclear power, celebrating 25 safe years since the meltdown which caused huge environmental damage and social adversity as communities were removed from the radiation zone. Both accidents have been rated a Level 7 (out of 7) on the International Nuclear and Radiological Event Scale (INES). Their causes are vastly different however. Chernobyl was the result of human error and faulty reactor design which would not have been allowed to be built outside of the very isolated system that was the Soviet Union (Simmons, 2012). In the case of Fukushima, the tsunami rather than the earthquake caused the damage[10]. The reactors were automatically shut down in response to the earthquake, which also cut off external power sources. The backup generators were swamped by the water, ultimately leaving the reactors without cooling systems and allowing Units 1, 2 and 3 to go into varying degrees of meltdown and breach their containment structures. While the design of the reactors incorporated substantial safety measures to deal with earthquakes, a tsunami of that magnitude had not been accounted for. Fukushima has now seemingly compounded the Chernobyl disaster as anti-nuclear sentiments again influence public opinion and acceptance of nuclear as an energy source.

In addition to these colossal disasters, there have been seven other nuclear accidents involving damage to the reactor and the release of radioactivity with the most notable of these warranting mention. In 1957 the Kyshtym disaster resulted when an explosion occurred at a Soviet nuclear fuel reprocessing plant; despite the fact that many people had to be relocated the secrecy surrounding the Soviet nuclear program kept this secret for many years. An area of over 800km^2 was heavily contaminated with radioactive material, and the health effects are believed to have been very serious, although due to the Soviet cover up of the incident only rough estimates can be made. The Kyshtym disaster was rated 6 on the INES scale and remains the third most significant nuclear accident behind Fukushima and Chernobyl. In the same year Great Britain had its own nuclear accident, similarly in a facility hurriedly built as part of the nation's nuclear weapons project. The Unit 1 reactor core of the Windscale Pile caught fire, releasing radioactive material into the surrounding environment. While no casualties resulted, the accident was rated 5 on the INES scale. The 1979 Three Mile Island Accident in Pennsylvania, USA was also rated a 5 on the INES scale and resulted in a very costly clean-up bill, however no health effects were detected. The major damage was to public opinion. In 1999 Japan had a fairly serious accident at the Tokiamura uranium reprocessing facility. Criticality was reached due to human error and safety breaches, and two deaths resulted. There have been a number of other "incidents", however none causing significant material damage[11].

Fukushima and these other accidents aside, the nuclear industry had been otherwise enjoying an improving safety record. According to the World Association of Nuclear Operators (WANO), the three most important plant-based performance indicators are: (i) the rate of unplanned 'automatic trips'; (ii) radiation exposure of workers, and; (iii)

[10] See Ferguson, 2011 for an explanation of 'How did the Fukushima Daiichi accident happen?' p163-167

[11] For more information on these see WNA website

discharge to the environment. These have all drastically decreased over the past 40 years (cited in Findlay, 2011). The WNA proudly states there are now 14,860[12] reactor-years of experience worldwide. Interestingly, the IAEA also makes the point that more people are killed each day in the extraction of fossil fuels than have been in the history of nuclear power. Nonetheless, it is obvious from these nuclear accidents that safety must be paramount at such facilities and that conditions are not always predictable making the risk of a nuclear accident very real.

The problem of spent fuel

Macfarlane (2011, p30) points out that "though nuclear power produces electricity with little in the way of carbon dioxide emissions, it, like other energy sources, is not without its own set of waste products" and indeed being radioactive makes them rather more delicate to deal with. There is still no widely accepted 'best method' of storage or disposal of spent fuel supplies, and, as there has not yet been many nuclear power plants decommissioned, the barometer for success is still undefined. Some 90% of the world's used fuel is stored in ponds, usually at reactor sites and occasionally at a central site and has been that way for decades[13]. Macfarlane (2011, p32) argues this is due to a lack of foresight and priority at the planning stages of a nuclear facility and points out that there may be little difference between a nuclear accident occurring at the front or back end of power production as both have similar consequences (p31). The real dangers of this have been made emphatic, again, by the Fukushima disaster.

The fuel ponds of Unit 4 of the Fukushima Daiichi plant were heavily loaded, containing 1331 used fuel assemblies[14] requiring substantial cooling. Once the cooling system had failed, the pond required about 100 m^3/day of water to replenish it. Though there may have been some damage to the containment of the pond, it seemed as though the main loss of water was due to evaporation. Either way, radioactive material was being lost to the surrounding environment from the overheating storage ponds. Macfarlane (2011, p32) claims that in the US and other countries, metal racks which hold the fuel in place in the pools have been adjusted to hold more than four times the amount intended. Given the dangers exemplified by the loss of cooling at the Fukushima plant, careful planning at inception of a nuclear energy program is necessary to deal with spent fuel and ensure adequate mid- to long-term management of the radioactive waste to minimise the risks of storing spent fuel.

As previously mentioned, the alternative to storage and eventual disposal of spent fuel is the reprocessing of used nuclear material, and this has been heralded as a major part of the solution to the problem of radioactive waste. WNA[15] reports that reprocessing can gain some 25% more energy from the original uranium and reduce the volume of high-level waste[16] to about one fifth. While these have been the primary reasons for reprocessing over the past 50 years, the last decade has seen interest in reprocessing grow with hopes that all long-lived actinides will be recovered and used in the futuristic fast reactors, ending up as short lived fission products. This will not only reduce the long-term radioactivity in high level waste but also reduce the possibility of plutonium being diverted from civilian operations, contributing hugely to

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[12] At 27/05/2012

[13] http://www.world-nuclear.org/info/inf04.html

[14] In comparison to 400 fuel assemblies in Unit 1 reactor, 548 in the reactors of Units 2-5 and 764 in Unit 6.

[15] http://www.world-nuclear.org/info/inf69.html 'Processing of Used Nuclear Fuel'.

[16] Waste material is classified as follows: exempt waste and very low level waste VLLW, low-level waste LLW, intermediate level waste ILW, and high-level waste HLW.

the proliferation resistance of the fuel cycle, which will now be discussed in more detail.

Proliferation risk and the need for non- proliferation

The dual purpose of nuclear technology has been briefly mentioned, with the technologies required for nuclear weapons programs existing at both the front and back ends of the nuclear fuel cycle. Nuclear reactors themselves are not directly a proliferation concern; rather the enriching and reprocessing technologies can be directed away from civilian purposes and used for weapons programs[17]. As mentioned, reactor fuel consists of uranium enriched to about 3-4% U-235; weapons grade uranium requires over 90% and anything over 20% is referred to as highly enriched uranium (HEU). Plutonium (Pu-239) can also be used for the production of nuclear weapons if enriched to 93%; spent fuel contains typically 60-70% Pu-239. Reprocessing technology allows enrichment of nuclear fuel, and although the technology required to reach weapons grade exceeds that for normal reprocessing, it is undoubtedly similar technology. Furthermore, as more nations acquire enrichment and reprocessing technology the verification of fissile material becomes more difficult. Similarly as more countries acquire more facilities the resources of the IAEA are stretched further and further, complicating the job of the watchdog.

Put bluntly:

> [T]he nuclear renaissance provides two additional challenges to the already shaky non-proliferation regime: as the use of existing civilian nuclear technology increases, so does the risk of its diversion and weaponisation; and the adoption of new technologies such as spent fuel recycling and fast (breeder) reactors provide new potential sources of proliferation (Ebinger and Massy, 2010 p85).

The need for non-proliferation is generally accepted. Though some have turned this line of thinking on its head[18], the general consensus is that the less these weapons spread, the safer the world will be – and vice versa. Hymans (2012, p2) makes the point that not only is proliferation threat a serious international security problem, but also that inflated estimates of nuclear capabilities are a problem too, encouraging the repetition of “unnecessary and disastrous ‘pre-emptive’ actions” such as the Iraq War. That is, the threat of a threat regarding nuclear status seems to determine international action. This only serves to highlight the centrality of nuclear weapons in international affairs of the modern world and makes emphatic the need to eliminate the occurrence, or indeed threat, of nuclear proliferation.

Objectives of this research

Having covered the basics of the nuclear energy industry and the associated risks, this research will now focus in more detail on nuclear proliferation. In the following section non-proliferation measures shall be outlined along with the ideas behind them. Subsequently, a multidisciplinary review of the proliferation literature shall be undertaken by categorising theories and highlighting linkages and interactions. A brief history of nuclear proliferation shall then be provided, linking theory and experience, before assessing the efficacy of the non-proliferation regime.

[17] http://www.world-nuclear.org/info/inf12.html

[18] See Waltz (1981) ‘The Spread of Nuclear Weapons: More May be Better’

1. Non- proliferation Measures

Early ideas

The devastation of atomic power was blatantly demonstrated in 1945 when the USA dropped bombs on Hiroshima and Nagasaki ending World War II in the Pacific Region. This prestigious show of power was accompanied with a great sense of guilt and the realisation of what had been unleashed with the hard work and unprecedented progress of nuclear physicists and scientists at the Manhattan Project. The supremacy of US military power was short lived however, with the Soviet Union testing its first nuclear device only four years later in 1949. The United Kingdom followed suit in 1952, France in 1960 and China in 1964. It was evident that what the US had originally thought to be their own secret weapon was spreading throughout the world and thus the issue of nuclear proliferation became a major topic in international politics.

As the nuclear arms race of the Cold War progressed into the 1950s, the stockpiles of weapons held by the USA and the Soviet Union became enormous[19] and, with tensions high, the very real danger of nuclear war was felt across the globe. While the threat of horizontal proliferation remained a concern, vertical proliferation20 was evident by the rate of increase in the nuclear arsenals of the two superpowers, and the destructive power of these weapons had also increased dramatically through improved accuracy of delivery and increased range of deployment, thus making such weapons exponentially more dangerous.

In 1953, US President Dwight Eisenhower addressed the General Assembly of the UN with his very famous 'Atoms for Peace' speech warning of the "awful arithmetic of the atomic bomb" and the possibility of total destruction. Faced with such danger, he expressed the desire of the USA to "be constructive, not destructive" such that "this greatest of destructive forces can be developed into a great boon, for the benefit of all mankind". Out of Eisenhower's vision of peaceful uses of atomic power the International Atomic Energy Agency was born and made responsible for the peaceful use of fissionable material around the world. He also alluded to complete disarmament. His vision of the USA's role "to help solve the fearful atomic dilemma" may have been premature, however out of this vision the non-proliferation regime evolved.

In 1957 the International Atomic Energy Agency (IAEA) was established under the umbrella of the United Nations family. The three pillars of the Agency's statute were (i) nuclear verification and security; (ii) nuclear safety, and; (iii) technology transfer. Ultimately the IAEA was established to spread the utilisation of atomic power for peaceful purposes only. Eisenhower's successor, John F Kennedy, expressed similar sentiments throughout his term of office, voicing concerns of the potential for fifteen to twenty nuclear armed states by 1975. This reflected the dominance of political realism at the time, and foreign policy was flanked with fears of a 'nuclear tipping point' prompting exponential proliferation. When JFK announced the signing of the Nuclear Test Ban Treaty in 1963, which banned all nuclear tests in the atmosphere, outer space and under water, he made reference to the Chinese proverb "A journey of a thousand miles must begin with a single step"21. JFK's prediction of over 15 nuclear states by 1975 never did eventuate22, but as international policy still flounders over

[19] Reportedly enough to destroy the whole world.
[20] Horizontal proliferation refers to the spread of weapons to new states whereas vertical proliferation refers to the build-up of nuclear arsenal within a state.
[21] http://www.ratical.org/co-globalize/JFK072663.html
[22] Most estimates of proliferation have been grossly overestimated.

the issues of disarmament and proliferation, his recognition of the difficulty with which nuclear power would be withdrawn from foreign policy and military applications proved true.

In 1968 the Treaty on the Non-Proliferation of Nuclear Weapons or the Nuclear Non-Proliferation Treaty (NPT) opened for signing and came into force in 1970, opening up a new era in which the non-proliferation of nuclear power for military purposes was normalised internationally. The NPT made the IAEA responsible for international oversight and implementation of safeguards designed to prevent nuclear proliferation. The NPT and the IAEA form the backbone for the global non-proliferation regime and will be discussed in more detail, however it is important to note that by 1976, Albert Wohlstetter had already pointed out fundamental flaws of the regime in his landmark essay 'Spreading the Bomb without Quite Breaking the Rules'; these flaws prove troublesome even today.

Contemporary ideas

Where policy makers have traditionally considered the threshold for nuclear power status to be the test of a nuclear device (test/no test assumption), contemporary authors and policy makers have started reconsidering the validity of this judgement. The idea of the "virtual nuclear weapons states" was made prominent by Mohamed ElBaradei, the former Director-General of the IAEA, and a shift in thinking of policy makers has been evident in pre-emptive actions taken prior to any formal weapons testing of countries suspected of attempting to proliferate. As Hymans (2010, p105) aptly notes, "although perhaps the overall proliferation process can indeed be conceptualised as a 'ladder', it has long been recognised that one of the rungs of that ladder must be marked in red".

A 'virtual nuclear weapon state' loosely refers to the material and technological capacity of a state to develop a nuclear weapons device over a relatively short length of time. The control of a nuclear reactor is critical to this definition, in that such a facility assures the presence of the technical know-how in the form of nuclear physicists and operators and also access to a significant quantity of fissionable material. The technical links between nuclear energy for peaceful purposes and for military purposes have been briefly discussed, and a fuller explanation remains outside the scope of this paper, however it is important to note that the increased ability of one will necessarily escalate the "virtualness" of the other through the "dual use" of equipment and technology. This has led authors to articulate the significant quantity criteria (SQ/noSQ assumption), which then gives rise to the 'virtual nuclear state': that is, a significant quantity of fissionable material is considered "virtually" a nuclear bomb.

Hymans (2010) presents a thorough discussion of the question "When Does a State Become a 'Nuclear Weapons State'". He makes emphatic the "important qualitative distinction between the two types of states, nonnuclear and nuclear" (p105). He argues the advantages of the traditional test/no-test criteria include a fit with the underlying concept and a reduction of room for politics and spin, and adds further that nuclear weapon stateness has been operationalised in the foundational text of the NPT. On the other hand, he points out that even this metric is not an indicator of interest itself, and questions whether the absence of a nuclear weapon test is a valid indicator of a non-nuclear weapons state. The SQ/no SQ indicator proves no less problematic, with Hymans citing several serious drawbacks. He questions the assertion of the appeal of "nuclear opacity" and highlights the problems associated with the interpretation of sensitive information and political bias in consideration of what is often classified as covert information. Furthermore, he claims that often the obstacles between SQ and bomb are underestimated and that “fissile material is not ‘the bomb’, and to equate the two is a fundamental error in terms of both social science and public policy” (p116). However, the technical links between atomic power for peaceful purpose or otherwise cannot be disregarded.

This technological duality has led to a heavy reliance on supply side measures in most non-proliferation objectives. Control of nuclear technology and fuel has been heralded as the most effective method of limiting proliferation. The result of this has been a huge number of treaties, agreements, safeguards and initiatives some of which will be discussed in more detail. Economic tools have also been an important aspect of these negotiations, such as trade embargoes and sanctions. Both the ‘carrot’ and the ‘stick’ approaches to non-proliferation are implemented through a complex web of multilateral, bilateral and unilateral institutions which give substance to the non-proliferation regime.

Institutional non- proliferation measures

Multilateral mechanisms

The Nuclear Non- proliferation Treaty

The NPT lies at the centre of the non-proliferation regime, and with 189 signatories can be almost considered a universal treaty – with the notable exceptions of Pakistan, India and Israel as well as North Korea which withdrew in 2003. The treaty recognises five nuclear weapons states (NWS) which had all tested weapons by 1968 when the NPT was drawn up. These are the USA, China, France, the UK and Russia (formerly the Soviet Union). All other parties to the treaty are considered non-nuclear weapons states (NNWS). The Articles have been summarised below in Table 1 (overleaf).

The significance of Article IV cannot be overstated; this “inalienable” right is the loophole of the Treaty which allows States to develop extensive nuclear programs which are then subject to interpretation as to their purpose. The provision of Article X is also an issue of contention, demonstrated no more obviously than when North Korea withdrew from the Treaty and followed with a nuclear explosion.

The International Atomic Energy Agency – the proliferation watchdog

The IAEA forms the centrepiece of the enforcement framework, having been designated by the NPT as the organization responsible for the oversight and implementation of safeguards in the prevention of nuclear proliferation. As has been previously mentioned, the Charter of the IAEA is the peaceful promotion of atomic energy; “the Agency works with its Member States and multiple partners worldwide to promote safe, secure and peaceful nuclear technologies”23. This “promotion”, however, brings about a somewhat conflicting role. On the one hand the IAEA is working to spread nuclear technology across the globe, and on the other has been made responsible for ensuring this technology is not used in ways other than peaceful. Levite (2010) has coined this the “schizophrenic mandate” of the IAEA.

Indeed, coupled with the emergence of the SQ/noSQ criteria for judging the level of nuclearisation of a country, this duality has proven to be hugely problematic.

[23] http://www.iaea.org/About/about-iaea.html

Table 1. Articles of the Nuclear Non- proliferation Treaty Source: UNODA http://www.un.org/disarmament/WMD/Nuclear/NPTtext.shtml	
Article I	Each NWS agrees not to transfer to any recipient nuclear weapons or nuclear explosive devices or assist, encourage or induce NNWS to manufacture or otherwise acquire or control nuclear weapons or explosives
Article II	Each NNWS agrees not to receive, control, manufacture or otherwise acquire nuclear weapons or explosive devices
Article III	• Each NNWS agrees to accept safeguards agreed with IAEA for the purposes of verification • States are not to provide fissionable material or associated technology to NNWS unless subject to the safeguards required • Safeguards to be implemented in a manner which complies with Article IV and avoids hampering economic or technological development • NNWS required to conclude agreements with the IAEA to meet the requirements of this Article
Article IV	"Nothing in this Treaty shall be interpreted as affecting the inalienable right of all the Parties to the Treaty to develop research, production and use of nuclear energy for peaceful purposes without discrimination and in conformity with Articles I and II of this Treaty" • All Parties to the Treaty have the right to exchange equipment, materials and scientific and technological information for the peaceful uses of nuclear energy
Article V	Each Party to ensure the spread of potential benefits from the peaceful application of nuclear explosions to NNWS on a non-discriminatory basis
Article VI	Each Party undertakes to pursue negotiations relating to nuclear disarmament
Article VII	States retain the right to conclude regional treaties to assure absence of nuclear weapons in their respective territories
Article VIII	Amendments to the Treaty are considered, and the Treaty to be reviewed
Article IX	The Treaty is open to all States for signature, and subject to ratification. Registered under the Charter of the United Nations
Article X	Allows Parties the right to withdraw from the Treaty if extraordinary events jeopardize national interest; three months notice must be given to all Parties to the Treaty and the UNSC. • Twenty five years after entry into force of the Treaty, a conference will be convened to direct the future of the Treaty

Under the system of safeguards, the IAEA takes on the extensive and complicated role of verification of nuclear material and technology. The Additional Protocol was adopted in 1997, increasing the inspection authority of the IAEA "in order to strengthen the effectiveness and improve the efficiency of the safeguards system"24. This grants the IAEA greater access to information and increased inspection powers among other things which enhance the capabilities of the IAEA in ensuring international safeguards are not breached.
While the IAEA is an independent international organisation, its relationship with the UN is regulated by special agreement and its reports annually to the UN General Assembly and the UN Security Council as deemed necessary.

The United Nations

The role of the United Nations in promoting non-proliferation has been instrumental. In 2004 the UN Security Council (UNSC) adopted unanimously Resolution 1540 which says that all Member States:

[24] http://www.iaea.org/Publications/Documents/Infcircs/1997/infcirc540c.pdf

“refrain from providing any form of support to non-State actors that attempt to develop, acquire, manufacture, possess, transport, transfer or use nuclear, chemical or biological weapons and their means of delivery”

“shall adopt and enforce appropriate effective laws which prohibit any non-State actor to manufacture, acquire, possess, develop, transport, transfer or use nuclear, chemical or biological weapons and their means of delivery”

“shall take and enforce effective measures to establish domestic controls to prevent the proliferation of nuclear, chemical, or biological weapons and their means of delivery, including by establishing appropriate controls over related materials”[25]
This effectively criminalises the spread of nuclear (and other) technology for the purposes of making bombs and engages the UN in dispute settlements when they are referred to the UNSC. In 2006 the UNSC adopted Resolution 1673 which extended the mandate of the 1540 Committee and intensified efforts for the implementation of Resolution 1540; it also called for improved reporting[26]. Resolution 1887 was adopted in 2009 which called on non-signatories to sign the NPT[27]. A number of UN organisations collaborate on issues relating to non-proliferation, such as the UN Counterterrorism Implementation Task Force and the UN Office on Drugs and Crime.

Regional organisations and Nuclear Weapons Free Zones

While the UNSC is at the head of these Resolutions, the role of regional and sub-regional organisations in implementing Resolution 1540 has been highlighted by Scheinman (2008) who claims that the “authority, legitimacy and confidence” (p5) placed in regional organisations (more so than in the UN) makes them an important tool in its implementation. They can help to strengthen weaknesses in the regime posed by cultural differences, perspectives of legitimacy, priority and capacity (see Scheinman, 2008).

The outcomes of these regional cooperations have been a number of declared Nuclear Weapon Free Zones (NWFZ).

1. <u>Treaty of Tlatelolco or the Treaty for the Prohibition of Nuclear Weapons in Latin America and the Caribbean</u>

This Treaty came into force in 1969 and prohibits the testing, use, manufacture, production, acquisition, receipt, storage, installation, deployment and any form of possession of nuclear weapons. Despite the notable failure of Cuba in ratifying the Treaty, otherwise “consensus regarding the banning of WMD in Latin America is profound” (Herz in Scheinman, 2008 p17) which she attributes to the view that “nuclear capability was seen as a stumbling block on the way to economic modernisation and technological advancement instead of a sign of global prestige” (p13).

2. <u>Treaty of Pelindaba or the African Nuclear Weapon-Free Zone</u>

[25] http://daccess-dds-ny.un.org/doc/UNDOC/GEN/N04/328/43/PDF/N0432843.pdf?OpenElement
[26] http://daccess-dds-ny.un.org/doc/UNDOC/GEN/N06/331/10/PDF/N0633110.pdf?OpenElement
[27] http://daccess-dds-ny.un.org/doc/UNDOC/GEN/N09/523/74/PDF/N0952374.pdf?OpenElement

This Treaty opened in 1996 but only entered into force in 2009 and obliges Parties legally to maintain the highest standards of security and effective protection of nuclear material, facilities and equipment. The Treaty also bans attacks on nuclear facilities. Findlay (2011, p134) praises the Treaty for “the most explicit compliance language applicable to nuclear security in any multilateral treaty” and sees it as a useful tool should civilian nuclear energy develop in African states. This is not necessarily a complete solution, however: du Preez and Dye (in Scheinman, 2008) point out that a lack of capacity and border controls make enforcement of the conditions of the Treaty very difficult as well as compliance with reporting standards.

3. <u>Treaty of Rarotonga or the South Pacific Nuclear Free Zone Treaty</u>

This Treaty declares the South Pacific a NWFZ and has been ratified by all signatories and makes positive linkages between non-proliferation instruments, such as export controls and economic development. Many small South Pacific countries do not adequately comply with reporting expectations and see the process as not entirely relevant to them; they have more pressing issues on which to focus their minimal resources (Ogilvie-White in Scheinman, 2008).

4. <u>Treaty of Bangkok or the South East Asian Nuclear Weapon Free Zone Treaty</u>

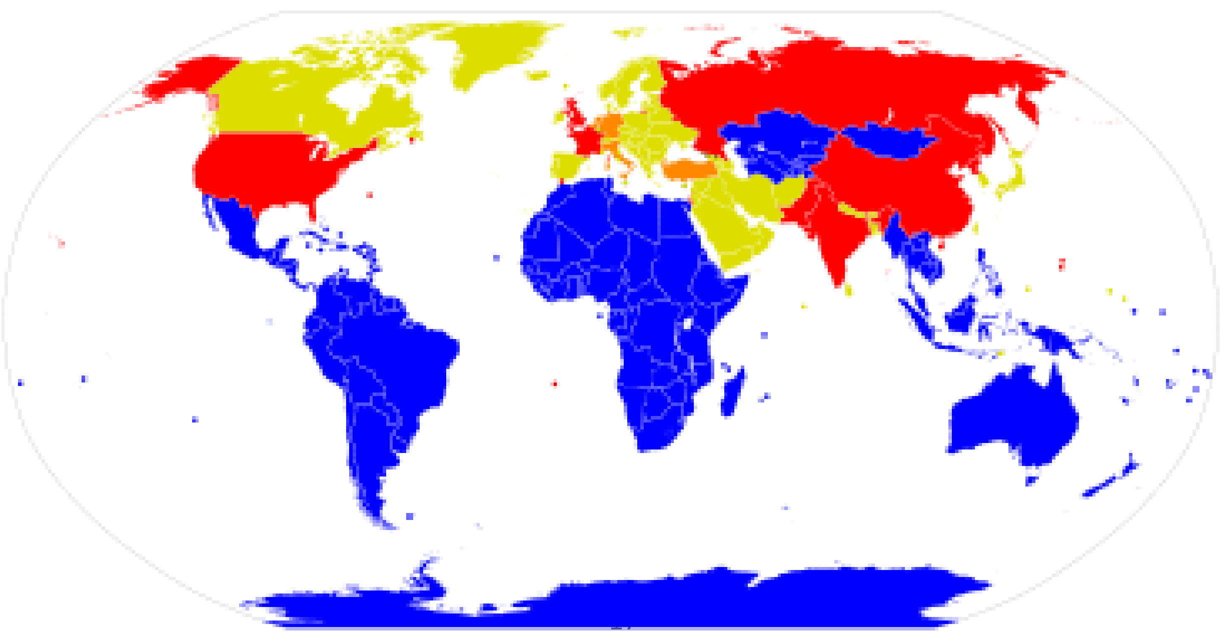
The SEANWFZ Treaty opened for signing in 1995 and entered into force in 1997. It obliges members not to acquire, develop, possess or control nuclear weapons.

5. <u>Treaty of Semei or the Central Asia Nuclear Weapons Free Zone</u>

This Treaty has been ratified by Kyrgyzstan, Uzbekistan, Turkmenistan, Tajikistan and Kazakhstan, and entered into force 2009 and is a legally binding agreement of States not to manufacture, acquire test or possess nuclear weapons.
Figure 3 shows in blue, areas which are covered by NWFZ agreements and represents 39% of the world’s land area. Countries in red on the diagram are NWS and those in green are Party to the NPT but no other nuclear weapons agreements.

Figure 3. Global coverage of NWFZ and declared nuclear states

Source: Wikipedia http://en.wikipedia.org/wiki/Nuclear_Weapons_Free_Zone



Multilateral treaties relating to nuclear non- proliferation

The Convention on the Physical Protection of Nuclear Material opened in 1980, came into force in 1987 and is the only legally binding multilateral treaty (Findlay, 2011 p131). The Convention facilitates the safe transfer, use and storage of nuclear material for peaceful purposes by stressing the importance of physical protection, strengthening the roles of the IAEA and other bodies in global governance and also making inappropriate uses of nuclear material punishable under State laws[28]. The Convention does not, however, apply to nuclear material deemed for military purposes and therefore leaves the Treaty wanting considerably.

The International Convention for the Suppression of Acts of Nuclear Terrorism opened in 2005, coming into force July 2007. This Convention obliges parties to establish offences within domestic criminal law relating to nuclear terrorism and obliges parties to share information relating to such matters. The Convention includes the unlawful possession of nuclear material under nuclear terrorism but does not include monitoring, verification or compliance provisions.

A number of initiatives have been designed to deal with the legacy of the huge stockpiles of Soviet nuclear weapons resulting from the arms race of the Cold War years. The US Cooperative Threat Reduction Program focuses on identifying, dismantling and securing WMD and associated infrastructure and technology in States of the former Soviet Union. The Global Partnership against the Spread of Weapons and Materials of Mass Destruction also aims to secure weapons lingering in the former Soviet States and ensure they do not fall into the wrong hands.

Nuclear supplier agreements have also been developed internationally to strengthen export controls and therefore maintain tight controls over nuclear materials from the time they are extracted in the mining process. The Zangger Committee was an outcome of the NPT and strengthens the safeguards of the IAEA by committing parties to the Treaty to not provide nuclear material or technologies to NNWS unless they are subject to the safeguards of the NPT. The Nuclear Suppliers Group (NSG) was formed after the Indian nuclear test of 1974 in an attempt to limit the international transfer of dual-purpose, nuclear useful materials. Today, the NSG "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"[29]. Guidelines are implemented on a national level, and ultimately not subject to uniformity which leads Findlay (2011, p151) to describe the group as a "political lightning rod" due to the sometimes divisive outcomes.

The Proliferation Security Initiative (PSI) is a voluntary collaborative arrangement, without the structure of an organisation. PSI activities focus on the development of maritime, air and ground interdiction capabilities and with a strong focus on international cooperation, seeks to prevent the illicit trafficking of weapons of mass destruction, their delivery systems and related materials[30].

This discussion has by no means been exhaustive with a number of other treaties existing under the non-proliferation framework (see Alger 2008, Findlay 2011 etc).

[28] http://www.iaea.org/Publications/Documents/Infcircs/Others/inf274r1.shtml
[29] http://www.nuclearsuppliersgroup.org/Leng/default.htm
[30] http://www.dfat.gov.au/globalissues/psi/

Bilateral mechanisms

There are a huge number of bilateral nuclear supply agreements which condition the sharing of civilian nuclear material and technology, forming a complicated and intricate web of arrangements relating to nuclear materials. The purchase or acquisition of nuclear technology usually involves some form of bilateral agreement between both the supplier and the IAEA and the recipient. For example, France has entered into at least twelve civilian bilateral agreements since 2000 with countries including Algeria, Jordan, Libya, Morocco, Tunisia, Qatar, UAE and India relating to the supply of nuclear technology. This is also the case with nuclear materials, such that suppliers of uranium (such as Australia) form bilateral agreements with the State's they supply the material to regarding its use.

There are a few notable bilateral agreements which have contributed significantly to the non-proliferation regime. In the Cold War Era, Soviet-US negotiations sought to limit both horizontal and vertical proliferation and in post-Cold War times, Russia has worked with the US to limit the spread of nuclear weapons and related materials, and discussions on disarmament continue. A few of these initiatives have been mentioned previously. The Brazilian-Argentine Agency for Accounting and Control of Nuclear Materials (also party to the Quadripartite Safeguards Agreement) and the Brazil-Argentina Nuclear Energy Application Agency are both bilateral mechanisms which facilitate the sharing of information and implementation of safeguards in South America.

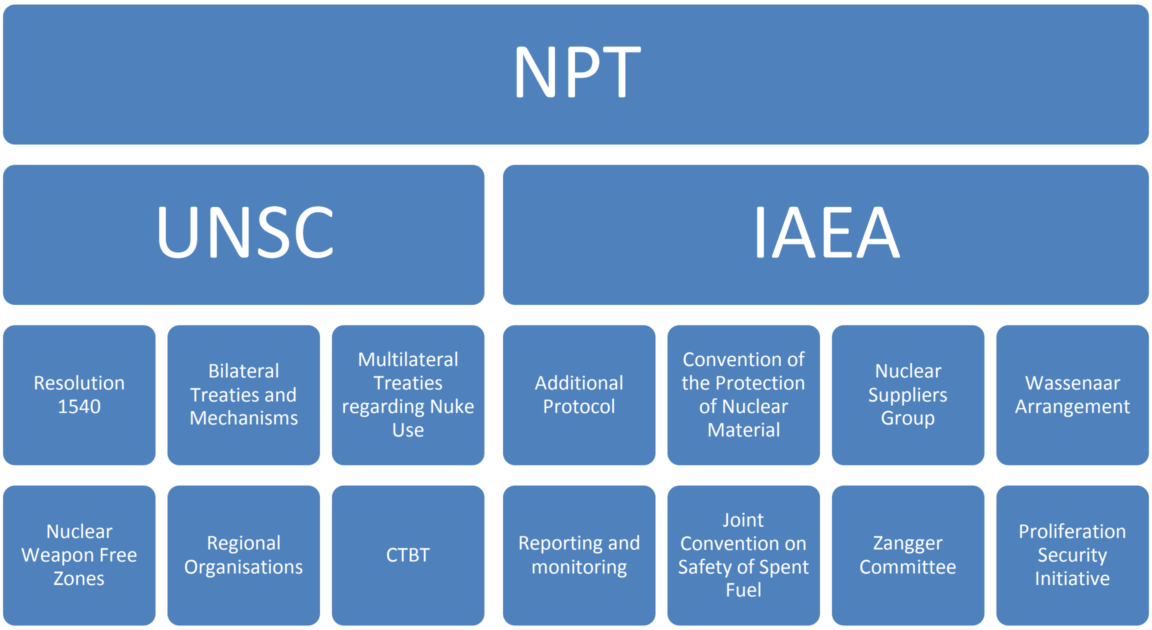
Unilateral Mechanisms

As previously mentioned, UNSC Resolution 1540 obliges parties to adopt and enforce appropriate and effective measures to prevent the misuse of nuclear material and technologies. The IAEA also obliges States to adopt certain measures and practices in dealing with nuclear materials and technologies. For example, nations seeking civilian nuclear technology must have an appropriate framework and institutional infrastructure to handle nuclear materials and technology. Despite the huge number of international and multilateral treaties and organisations designed to counter nuclear proliferation, State's must ultimately take responsibility for activities within their own borders for these other measures to be effective. Without the whole-hearted cooperation of States in the non-proliferation regime, the ability of the international institutions is diminished due to the scale of the issue.

Non- proliferation measures in summary

NPT forms the core of the non-proliferation regime with the IAEA acting as the watchdog and enforcer and the UNSC as the overseer and punitive mechanism. These are strong international institutions with appropriate authority, however loopholes in the legislation do exist, and as with any issue on the international stage it can be impossible to have all parties in agreement. This weakens the system and results in problems relating to enforcement and therefore ultimately leaving nuclear proliferation as a very real possibility. Figure 4 shows the core building blocks of the regime, with IAEA at the forefront as the watchdog, the UNSC with punitive power and a host of other mechanisms which altogether work toward prohibiting the spread of nuclear weapons.

Figure 4. The building blocks of the non- proliferation regime



2. Theories of Nuclear Proliferation

> The conventional view of proliferation is that a country's leadership at some point makes an explicit decision to seek a nuclear weapon, launches a secret program and finally achieves nuclear status by testing a device on a particular date. In reality the path to nuclear weapons capability requires many important and complex choices along the way. (Deutch, 1992 p124)

The above quote highlights the complexity of nuclear trajectories, nuclear decisions and ultimately nuclear proliferation (or non-proliferation). Because the technical and industrial barriers to nuclear weapon development are high, the road to nuclear weapon status can be long, windy and expensive. It can evolve over the lifespan of various governments; it can be spearheaded by non-state actors; various forms of help are often sought from outside nations or their members; intervention may occur from inside or outside parties. What *is* common in nuclear trajectories is that domestic actors are not always in agreement regarding nuclear decisions, and both inside and outside parties will always have differing views as to the appropriateness of a State's nuclear policies and actions. These complexities, combined with the often covert nature of the associated operations, mean that there is, as yet, no clear consensus on the causes of proliferation in the academic literature. Furthermore, theories of nuclear proliferation cannot be considered entirely separately to more broad international relations theories and philosophy in general. While some consideration has been given to these various perspectives, it is beyond the scope of this paper to get caught up in philosophical debate. Therefore, only where relevant have they been mentioned.

The proliferation literature has traditionally been divided into two camps: that which focus on demand side explanations of proliferation and that which focus on supply side explanations. That is, some scholars consider would be proliferators to be motivated by the desire for nuclear weapons capability while others consider the development of a nuclear weapons program to be more the result of the ability to do so. Sagan (2011, p226) argues, however, "that the supply-side literature has mistakenly focused on inaccurate measures of nuclear weapons capabilities, while the demand-side literature has paid inadequate attention to how the Non-Proliferation Treaty (NPT) and related institutions of the broader non-proliferation regime influence incentives for and against nuclear weapons acquisition". He argues further that this division has "focused scholarly attention away from understanding the relationship between supply and demand". Indeed, the topic of nuclear proliferation is such a complex and integral part of international relations that one should be wary of accepting one school of thought over the other.

While it is important to keep this traditional approach in mind, a review of the literature will be undertaken from a multidisciplinary approach. Rather than reviewing under the conventional demand / supply split, the literature will be considered as contributing in five broad ways as outlined by Lynne-Jones (2010, p xii-xiii) in response to the question:

> What motivates them [states] to devote resources to acquiring nuclear materials, technologies, and knowledge and combining them to build bombs?

He provides five explanations which, I believe, summarise the proliferation literature succinctly while simultaneously providing both divisions under which we can more closely examine the theories and research relating to the issue of proliferation and also consider the different motivations on a state by state basis when analysing historical information. These explanations can be summarised as follows:

i. Nuclear weapons are sought by states to enable them to counter security threats.

ii. Internal organisational dynamics are more important than international explanations in proliferation decisions.

iii. Nuclear proliferation may be constrained or encouraged by international norms resulting from regimes such as the NPT.

iv. External incentives and disincentives may interact with domestic factors such as global integration, structure and internal political economy.

v. States with access to nuclear technology will be more likely to acquire nuclear weapons.

It may be argued that breaking up the literature further than the traditional supply/demand split is to lose even more of the relationship between supply and demand. However, given the volume and diversity of the proliferation literature it is likely to be beneficial to first identify common themes and consensus views as well as outlier theories and new ideas before then stepping back to look at the bigger picture. An interesting point is raised by Levite's (2002/03, p64) claim that a "shortcoming in the existing literature is its failure to explore the possibility that the rationale for developing (or for that matter retaining) nuclear weapons may change over time, with new rationales for doing so emerging to replace older ones that have lost some of their luster". This highlights that proliferation motivators need not, indeed should not, be considered as a one way street throughout the development and retention periods of nuclear programs. Such monolithic theories will surely fail to account for trajectories over time and therefore prove to be inadequate.

This paper does not seek to advance one view over another, but rather present the credible work which has been done by scholars to date to set the scene for further analysis. The review shall begin by breaking down the literature before taking a more holistic approach.

Security: nuclear weapons to counter threats

The role of security in nuclear proliferation can hardly be overlooked. The quest for military superiority, or at least equality, has long been entrenched in international relations. Dating as far back as the 3rd millennium BC military conquests have expanded cities into states31, and consequently empires have been taking stock of the arsenal of the enemy and aiming to do better. In the shaky post-WWII era, it was 'security' which fuelled the arms race between the USA and the Soviet Union and made various countries consider a nuclear arsenal a desirable feature of their military capabilities. It is a significant and intuitive driver of nuclear proliferation, and weapons and military proliferation more generally.

The security explanation of nuclear proliferation is rooted within political realism, which assumes "that power struggles are intrinsic in human nature, or at least in the anarchic real world, and that structural restraints such as balance of power arrangements are the only effective checks on conflict" (Rohmann, 1999 p337). The dominance of this philosophical assumption in the post-war era led to a near-consensus among policy makers, world leaders, political commentators and scholars alike that the proliferation of nuclear weapons could be primarily explained as responses to security threats faced by states: that is, nuclear weapons will be sought by states facing significant military threats which cannot be extinguished by other means. Since the ultimate weapon is the nuclear bomb, it thus also becomes the ultimate tool of security and, as a result, an object of desire for any state seeking to enhance their security.

Consequently, an enormous amount of writing has focused on this explanation of proliferation in both political and academic circles. Succinctly put is the claim that "the fundamental motivation to seek a weapon is the perception that national security will be improved" (Deutch, 1992 p124) reflecting this traditional view. The introduction of security 'perception' into explanations of nuclear proliferation, however, brings about a whole other facet of the argument; this shall be discussed in more detail. For now, in its most simple form, the history of nuclear weapons proliferation as explained by the security model goes something like this:

> The US developed atomic weaponry in 1945 at the height of WWII in response to global threats, the possibility that the Germans may build the bomb first and the desire to end the war. Post-war rivalry between the superpowers caused the Soviet Union to ramp up its efforts in nuclear development, achieving bomb status in 1949. Tensions remaining from WWII meant that both Britain and France desired nuclear security, and tested their first bombs in 1952 and 1960 respectively. In the East, China felt threatened by its nuclear armed neighbour, the Soviet Union, and the bossy 'peacekeeper' the United States, and by 1964 had tested their first bomb. This led to Indian insecurities and apparent nuclearisation; neighbouring Pakistan then felt it also needed nuclear weapons in its arsenal. In 1998 Pakistan was able to respond to the Indian testing of a nuclear device within two and half weeks. Similarly, the small country of Israel, being surrounding by unfriendly neighbours, sought to bolster its

[31] http://www.ancientmilitary.com/

national security through the acquisition of nuclear bombs. Atomic power in this part of the world drives Iran and Iraq to develop nuclear programs, and so on.

This theory of nuclear proliferation is certainly intuitive and explains these proliferation decisions with relative ease. When a nation is facing security threats it will seek the ultimate weapon of deterrence, and that is to date a thermonuclear weapon followed by a nuclear weapon.

Alternatively, one could argue that the security situation of any nation is necessarily a "perception", or a subjective rather than an objective position; this opens up the door for the security explanation. Müller and Schmidt (2010) comment that it is in fact security "perception" which plays a role in decision making. And indeed, historical cases of proliferation can, and have, all been satisfactorily explained using this theory. When one considers the various state leaders perceptions of security retrospectively it is rather simple and seemingly straightforward to attribute historical decisions to what "must have been" the perception of the security situation. Furthermore, the complementary and logical assumption to this theory is then that states which do not face (or at least perceive to face) such threats will not develop nuclear weapons. Indeed, it is difficult to imagine a situation whereby a state without security concerns would channel the required resources into a nuclear weapons program. It seems so simple and obvious. On closer inspection, however, the security model of proliferation is not the one-stop-shop for proliferation theories.

There is indeed, a substantial body of literature credibly theorising the role of security in proliferation, and certainly proliferation trajectories should not be examined without consideration of the external security environment. Additionally the focus on the security explanation is implicit in a large number of security aimed policies developed and undertaken by states, reflecting this assumption of causality by policy makers. Sagan (1997, p57) points to two policies which can be produced in response to such a security threat: strong states can devote resources to developing their own nuclear weapons, and weak states "do what they must" by forming alliances with nuclear powers thereby gaining extended deterrence. The idea of the "nuclear umbrella" was a practical response to this line of thinking: by guaranteeing the security of non-nuclear states through bilateral assurances of nuclear protection, the motivation for developing nuclear weapons by the NNWS would be removed and therefore non-proliferation would be achieved. Certainly, states such as the Soviet Union, China, Britain and France followed the former path while states such as Japan, Germany and other NATO[32] members, as well as Australia, followed the latter. The US nuclear umbrella has been very wide indeed. This has been a reasonably successful tool in the non-proliferation regime, although clearly not the silver bullet. The period 1945 until around 1995 was dominated by this conventional view that the nuclear umbrella provided over Europe and Japan meant "proliferation is not a problem, and peace is not a problem, precisely because the United States is remaining around as a nuclear policeman" (Quester, 1977 p73). Complementary to this was the conviction of the time reflected in the oft quoted words of the former US Secretary of State, George Schultz; "Proliferation begets proliferation".

The assumption that a threatened nation would desire atomic weaponry has historically led to hugely inflated forecasts of proliferation. If nuclear proliferation is the result of the desire to sure up national security, then why do so few nations possess the bomb? That so few of the 15 to 25 countries predicted by JFK in 1963

[32] The North Atlantic Treaty Organisation

(among many others) to develop nuclear weapons have done so cannot be adequately explained by the security theory of nuclear proliferation. This has led authors to develop more diverse and thorough explanations of both proliferation and non-proliferation. The subject has not been divided, but rather the standard of a theory is now assessed on its ability to explain what has been the trajectory of nuclear proliferation[33].

In 1997, Scott Sagan's article 'Why Do States Build Nuclear Weapons?' presented a hugely influential argument challenging conventional wisdom. He argued that although security plays a significant role in proliferation, it is not an adequate explanation, and therefore policies only targeting security will also prove inadequate. He claims that "an all too common intellectual strategy in the literature is to observe a nuclear weapons decision and then work backwards, attempting to find the national security threat that 'must' have caused the decision." (p63) He similarly accuses scholars of using this backward methodology in explaining cases of nuclear restraint or reversal. In presenting his watershed "Three Models", Sagan makes the point that "nuclear weapons, like other weapons, are more than tools of national security; they are political objects of considerable importance in domestic debates and internal bureaucratic struggles and can also serve as international normative symbols of modernity and identity" (p55). In this paper Sagan builds the foundations for what becomes the demand side of the proliferation literature, centred on three conceptual drivers, or models, of proliferation: the security model, the domestic politics model and the norms model. Much of the ensuing literature makes these categorisations.

Sagan had not been the first to challenge conventional wisdom. Etel Solingen's 1994 article 'The Political Economy of Nuclear Restraint' pointed to many faults in the security model. In it, she claims "while their security concerns have been more or less constant for over thirty years, the nuclear postures of some of these countries have shifted over time. The external security context in and of itself is not enough, therefore, to advance our knowledge about why these states embraced different instruments, at different times, for coping with such fears." (p36) And furthermore she argues that "the pursuit of security simply does not tell us enough about differences across space nor changes over time." (p39) Ultimately, despite finding support for the notion that existential security is very important in some cases of nuclear policy making (2007, p250), Solingen finds this explanation deficient.

Noting that nuclear weapons have not actually been used since 1945 and are rarely threatened, Beardsley and Asal (2009, p278) bring into question the use of nuclear weapons as coercive devices in making credible threats. The role of nuclear weapons in coercive diplomacy is beyond the scope of this study, however Beardsley and Asal's quantitative analysis of the benefits derived from nuclear weapons in crisis bargaining strengthens the argument that security considerations are the main, but not only, motivator for nuclear proliferation. They assess crisis outcomes from 1945 to 2000 using the International Crisis Behaviour data set and find that "nuclear weapons provide more than prestige, they provide leverage" (p296). That is, nuclear actors are more likely to overcome a nonnuclear state in a crisis. This leads the authors to conclude that the use of nuclear weapons in coercive diplomacy must be crucial to any explanation of why states acquire them. Perkovich (1998) has also argued that security threats do not always drive states to seek nuclear weapons, and has similarly pointed out the shortcomings of this theory of proliferation claiming it "purposely obscures the technological, political, and nationalistic impulses" (p17). While Beardsley and Asal

[33] The actual trajectory of many countries is often not black and white, however, due to the classified nature of much of the relevant information and the secrecy of nuclear programs in most instances. This complicates the job for theorists.

found security to be the main incentive driving state's toward nuclear weapon possession, they also concluded that the general level of demand for nuclear weapons should be such that the low rate of proliferation should be explained more by supply side factors (2009, p297).

The security explanation can be used to account for cases of non-proliferation when it can be argued that abstaining from nuclearisation enhances the security position of a state, or having nuclear weapons could actually decrease a state's security. For example, a state may totally renounce nuclear capabilities "to avoid escalation and instability, or to induce the other side to accept regional denuclearization" (Solingen, 1994 p39). This has been used as a diplomatic tool by several countries, most notably Japan. North Korea's renunciation of nuclear weapons has also been used as diplomatic leverage over the years, although its unwillingness to follow through on agreements has worn a little thin34.

When considering the nuclear industry more generally, rather than simply the possession of a nuclear bomb, referring back to Hyman's (2010) discussion of the classification of a nuclear state serves as a reminder that perhaps bomb acquisition is not entirely necessary. By acquiring the essential programs for bomb development under the guise of a civilian program certain security targets may be achievable without having to turn out actual bombs through 'virtual nuclear weapon' status. Case in point: Iran's development of enrichment technology. Not the bomb, but nearly. This makes emphatic not only the issues associated with how nuclear status is defined, but the problem at hand of spreading nuclear technology without spreading nuclear weapons. One point worth mentioning is also that proliferation is often only considered a 'problem' if there is already some existing security issue. For example, Israel's acquisition of nuclear weapons is not generally considered a 'problem' in Western literature but Iran's potential to do so is. On the other hand, Israel's possession of the bomb is, from an Iranian viewpoint, an unacceptable security threat.

The role of security in motivation to develop nuclear weapons must always be considered. While security cannot be considered sufficient to entice leaders to choose the nuclear path, it is considered a necessary condition that a nation perceives a threat to its national security in order to devote the huge amount of resources required to bomb development. We shall now turn our focus to another prominent motivator.

Domestic factors: more so than international

Solingen had begun alluding to a domestic politics model by 1994, but it was not overtly outlined until 1997 by Sagan's aforementioned "Three Models". This model now has an unquestioned place in the proliferation literature, having been both critiqued and consolidated in the years following. The model focuses on "the domestic actors who encourage or discourage governments from pursuing the bomb" because regardless of the effect on national security, the acquisition of nuclear weapons is "likely to serve the parochial bureaucratic or political interests of at least some individual actors within the state" (Sagan, 1997 p63). Taken to the extreme, the argument goes further that "nuclear weapons programs are solutions looking for a problem to which to attach themselves so as to justify their existence" and security threats "are merely windows of opportunity through which parochial interests can jump" (p65).

[34] The Economist 3rd March 2012 'A horse worth the price'
http://www.economist.com/node/21548944

Whereas the security model looks at outside pressures on states making nuclear decisions, domestic politics models disregard these international pressures (to varying degrees) and consider the internal, structural and political systems to be causes for decisions to pursue or forgo nuclear programs. The incorporation of domestic politics into the proliferation literature mirrors the widening of scope in theories of international relations more generally, which has many different implications when applied in the proliferation literature.

Although traditionally the literature focussed heavily on security explanations of proliferation, Hymans (2011b, p154) argues that now the "overwhelming majority of scholarly work" supports the notion that states' nuclear weapons choices are not a direct response to the international environment. Instead they "filter security challenges through one or more 'domestic prisms'." He goes on to note that particular "domestic prisms" regarded by authors include top state leaders' national identity conceptions, the economic interests of their core political support base, the empire-building desires of state bureaucracies, and wider societal norms. Each of these corresponds to prominent scholars and their work in this field whose research will now be discussed.

Perhaps not surprisingly, the first "domestic prism" mentioned by Hymans refers to his own work. He has written extensively on the role of the top state leaders' national identity conceptions (NICs) in state decisions to develop nuclear programs, with his award winning book 'The Psychology of Nuclear Proliferation: Identity, Emotions, and Foreign Policy' (2006) presenting this line of research. In this work, Hymans addresses the question as to why so few states have proliferated, develops a theory based on the psychological attributes of leaders and empirically builds support for his theory using content analysis of leaders' major public speeches, along with some other sources. He considers the NIC of state leaders to be distinguished along two dimensions. The first concerns "solidarity" and results in the development of an oppositional identity under an "us versus them" approach; or if commonalities are perceived then a "sportsmanlike" identity is defined. The second dimension relates to status, with a nationalist conception characterised by feelings of being equal or superior; a subalternation evolves from a sense of being subordinate. These two dimensions ultimately produce four "types"; Hymans argues that proliferation will only occur when the top state leader is an oppositional nationalist type.

Having carefully developed the constructs of leaders' NICs, Hymans then goes on to measure these using content analysis on speeches of the leaders of France, Australia, Argentina and India. He finds strong support for the notion that individual leaders are largely responsible for decisions to develop nuclear weapons programs. Hymans (2008) applies this analysis to North Korea, and finds "omnidirectional oppositional nationalism" (p269) throughout the dynasties of both Kim Il Sung and Kim Jong Il. Using a comparative foreign policy approach he argues that fear and pride, which have been amplified by the Korean War and Cold War more generally, are at the root of DPRK's nuclear ambitions rather than the oft assumed deterioration of its external security environment. He makes some bold arguments, claiming "the nuclear ambitions of any state are thus better understood as the product of emotions" (p260) and that "oppositional nationalism is typically at the root of decisions to go nuclear" (p271).

More recently he has argued for the "historical institutionalist, veto players perspective" (2011b, p156) which he considers to be "a start to what needs to be done to develop a full-fledged institutional perspective on nuclear proliferation" (p189). The analysis is premised upon the "veto players" who must be in agreement for a radical change in nuclear policy. Hymans argues that "ceteris paribus, the more veto players, the less likely the decision to seek nuclear weapons" (p 155). He goes on to conduct an in depth case study of Japan, a country which is often considered a "virtual nuclear weapons state" due to a combination of its high level of technical knowledge and capacity, and its possession of large quantities of separated plutonium. Hymans claims that due to the increasing number of veto players in Japanese politics since the 1950s, the country's nuclear policy has become increasingly difficult to change. What was once a specific policy of nuclear hedging has now been strengthened due to "powerful forces of inertia" (p188) rather than an unambiguous desire to adhere to such a policy. In fact, Hymans contends due to privatisation of a large part of the Japanese civilian nuclear power industry and the variety of veto players throughout the political system, that Japan is very unlikely to change its nuclear policy; and even in the event of a nuclear policy revolution, changes would not be brought about overnight or in a shroud of secrecy. This is a new development in the proliferation literature and more recently Hymans has applied his analytic expertise in explaining the seemingly increasing difficulty with which modern proliferators are able to achieve their aims (Hymans, 2012).

The second "domestic prism" refers primarily to the work of Etel Solingen, another prominent scholar who has already been mentioned and supports the notion that domestic politics are fundamentally relevant to nuclear policy. Her theory is based on the observation that differences exist in nuclear policy despite unchanged external security contexts and consequently she develops the argument "that examining the economic component of domestic liberalisation in the different regional contexts" will aid in accounting for regime creation (1994, p37). She also has written an award winning book, 'Nuclear Logics: Contrasting Paths in East Asia and the Middle East' (2007) which builds on her early writing, mounting a thorough and resounding argument that internationalising models of political survival are less likely to undertake nuclear weapons development than inward-looking, nationalist models. In the book she compares the nuclear trajectories of the Middle East and East Asia and finds support for her theory given that East Asia has tended toward denuclearisation and the Middle East has done the opposite.

Solingen makes the interesting point that leaders are much more likely to advertise nuclear decisions as "reasons of state" and thereby appealing to ideas of national security, global institutional factors and norms than they are to announce such decisions as the product of domestic political motivations (p275). Therefore, she argues that even partial support for the theory of domestic politics results in considerable substance; even claiming that "models of political survival and nuclear policies are not merely loosely associated but indeed joined at the hip" (ibid).

More specifically, Solingen makes a number of suggestions as to the causal pathways by which models that emphasise economic growth and openness to the global economy as tools of political survival make leaders tend more toward denuclearisation than others. These include the requirement to appeal to foreign investors, neighbourly relations in preserving regional cooperation and stability, ensuring secure access to international markets, upholding reputation at home and abroad, and the cost of alienating domestic agents of internationalisation (p275-6). Conversely she argues that nuclearisation serves the purposes of "foes of internationalization"; nuclear weapons are regarded as assets in building regime legitimacy by inward-looking models whereas outward-looking models regard them as liabilities (p77). The "roadmap" as summarised by Solingen is depicted in Figure 5, illustrating the axioms of regime characteristic and the corresponding expected nuclear behaviour.

Figure 5. Models of political survival and nuclear outcomes: Four scenarios

Taken from Solingen 2007 p287

	Internationalizing	**Inward- looking**
Denuclearization	1. Compatible	2. Anomaly
Nuclearization	3. Anomaly	4. Compatible

As do other theorists of nuclear proliferation, Solingen notes that there are exceptions, however that these are the anomalies, as indicated in Figure 5. Thus the norm for inward-looking models of political survival is nuclearisation; the norm for internationalising models of political survival is denuclearisation. She describes the theory as “probabilistic, bounded and, refutable” (p18) which summarises nicely the point that not all cases of domestic orientation to the global economy follow the proposed nuclear trajectory; that Solingen openly admits the model is not bulletproof is commendable. Many other authors are able to escape this clause by bending their arguments for such exceptions.

Although both Solingen and Hymans have been criticised for paying too little attention to outside factors (Müller and Schmidt, 2010) the depth of their relative analyses and theoretical propositions is such that their contribution to the proliferation literature has been significant and offers a thorough counterpoint to what had previously been an inadequate framework for the topic. Through works such as these the role of domestic politics in shaping nuclear policy has been accepted as significant.

The third “domestic prism” mentioned is the desires of state bureaucracies. In an in depth study focussing on Australia and Egypt, some counter intuitive claims have been supported. Walsh (2001, p269) found that neither threats, technology, or money determined whether or not a bomb would be built; rather “an identifiably small group of organizations and individuals working within a particular decision process” make that determination. He found politics and institutions to be of decisive importance (p13) and pointed out that in certain instances both superpower guarantee and NPT commitment have had the opposite effect and actually fuel nuclear weapon aspirations; an exceptionally unusual conclusion, which merely goes to show the explanatory of power any theory must be limited when attempting to blanket all cases. Tokhi (2010) also explores the effect of the divergence of group preferences over nuclear policy and the different structure and functioning of authoritarian institutions, finding that neither alone is a sufficient explanation for nuclear policy. His analysis of Egypt and Iran led him to conclude that international and/or regional developments can act as a catalyst for domestic response (p26). This again highlights the interactions between international and domestic conditions as being significant in nuclear policy decisions. Perkovich (2006, p357) also claims that “as long as the leaders of countries fear that internal opponents or outside powers may try to force political change on them, nuclear weapon capability may be desired for regime protection”.

The fourth “domestic prism” referred to by Hymans is wider societal norms. Maria Rost Rublee has contributed hugely in describing the mechanism by which international norms are formed. This shall be discussed in the next section however, highlighting the inadequacies of separating out theories of proliferation which often overlap and are always interlinked. Nonetheless, the merits are a more focused review and incremental additions to our wider understanding of nuclear proliferation.

In summary, domestic politics plays a significant role in nuclear policy making. Since nuclear decisions are necessarily made by people within the hierarchies of a nation state, the environment surrounding those people and ultimately the decisions must have an impact on the resulting policies. Whether it can be concluded that domestic politics are more important than other relevant factors may only be possible on a case by case basis, making a general theory of proliferation very difficult indeed. However, the acknowledgement of the significance of domestic influences on nuclear trajectories has been an invaluable contribution to the literature.

International norms: as both motivators and inhibitors

Similar to domestic politics work, the literature on international norms pays attention to the fact that proliferation has been so rare in the years since the development of nuclear power and its military applications. Let us first be clear as to what a "norm" is. As defined by the Oxford dictionary:

> norm *(noun)* 1 (the norm) the usual or standard thing: *strikes were the norm*. 2 a standard that is required or acceptable

This explanation of proliferation is therefore quite separate to the realist perspective, rather being premised upon social constructivism. There is nothing straightforward and simple about this line of thinking, which makes the relevant literature quite varied and very interesting reading. Most revolve around the notion of a norm associated with non-proliferation. That is, non-proliferation has become the norm, although some authors argue the high regard of nuclear weapons creates a norm which favours proliferation. However, authors are not in consensus as to how these norms have been created and what influence they have. In a typical chicken and the egg scenario, some authors claim the NPT led to the norm of non-proliferation, while others claim that the developing norm of non-proliferation facilitated the Treaty. And having established this regime, what mechanism now affects policy makers' nuclear decisions?

Rublee has made a major contribution in this area. In her landmark book 'Non-proliferation Norms: Why States Choose Nuclear Restraint' (2009), she applies the social psychology literature to the topic of nuclear proliferation, claiming that "neither realists focusing largely on threat nor liberals focusing on economic incentives can explain why these forty states chose not to acquire nuclear weapons" (p2). She argues that the application of social psychology literature to nuclear policy development is appropriate since decisions are usually made by small elite groups of officials, even in democracies (p16). Many authors acknowledge that international norms play a role in proliferation, but very few attempt a holistic explanation as to the mechanisms which facilitate this influence.

By recognising that although nuclear forbearance may be a common behavioural outcome among states but the reasons behind the actions are different, Rublee (2008, p424) is able to explain nuclear forbearance as the result of three different attitudes which bring about behavioural change: persuasion, identification, and conformity. Persuasion represents a change in preferences; conformity is when preferences have not changed; and identification is somewhere in between35. This leads Rublee to argue that "undermining the NPT could lead to a wave of nuclear proliferation among states we assumed would never think about the nuclear option again" if NPT commitments have been undertaken based on attitudes other than persuasion. Furthermore, she explores the mechanisms by which a "norm" regime (in this case the NPT) influences elite decision making, focusing on how norms are processed and the

[35] For a more thorough explanation see Rublee 2008 p445 and also Rublee 2009

conditions that affect norm potency. Using Japan as a case study, Rublee contributes to the literature relevant to nuclear policy making and demonstrates how norms can act as both motivators to acquire nuclear weapons or as motivators to forbear nuclear weapons.

As with Hymans and Solingen, the depth and difference of Rublee's work makes it a valuable contribution to the proliferation literature which had been otherwise lacking a thorough analysis of the mechanisms by which norms influence nuclear policy. Again, however, the theory is not good enough that other work should be ignored.
Taking a step back and looking more broadly at global sentiments towards nuclear weapons, it can be seen that a norm of non-use has been developed, evidenced by the lack of nuke use since 1945. Tannenwald (2005, p8) examines the origins of this "nuclear taboo", which she identifies as "a de facto prohibition against the first use of nuclear weapons". Noting that although nuclear weapons have not been successfully criminalised due to opposition from the US, among others, "legal use has been gradually chipped away through incremental restrictions" (p10) inflicted by treaties and institutional measures. The taboo is differentiated from a norm, and is argued to be more about the belief than the behaviour. Tannenwald (p12-13) goes on to propose four pathways by which the nuclear taboo develops:

i. Societal pressure induces the taboo via a bottom up process of normative change which leads to policy changes

ii. Normative power politics whereby states seek to publicly delegitimise weapons which confer power advantage

iii. Actions of individual state decision makers foster nuclear restraint

iv. The iteration of non-use over time results in a convention which results in an obligation

This theme is very similar to Rublee but rather than focusing on the NPT as the driver of outcomes, it begs the question, why have a nuclear weapon without the intent of using it? A country with the genuine intention of never using a nuclear weapon would have trouble justifying the costs incurred in acquiring one.

The aspect of trust in the international nuclear order is explored by Ruzicka and Wheeler (2010), who point out that the presence of trust has been given inadequate attention due to the general focus on the lack of trust or distrust. A trusting relationship is defined as "one into which actors enter knowing that as a consequence they increase their vulnerability to other actors whose behaviour they do not control, with potentially negative consequences for themselves" (p72). This makes emphatic the relevance of trust to the proliferation literature. Ruzicka and Wheeler argue that the NPT represents a trusting relationship since without trust there would have been no incentive for parties to sign; "in accepting the treaty, they exhibited trust, no matter how weak" (p75). The role of trust in non-proliferation is hardly a holistic theory, however it contributes to our knowledge and understanding of the regime by expressly pointing out trust as a necessary condition for states to choose nuclear non-proliferation, and in its absence can contribute to a state's desire to acquire nuclear weapons.

The notion of a "norm" can also be used to account for cases of acquisition, or attempted acquisition, of nuclear weapons. Johnson (2010, p429-430) aptly notes that while a norm developed in the 1950s against the use of nuclear weapons, no such normative barrier developed against the possession of nuclear weapons and that in fact “the possession – that is to say, the successful acquisition – of such weapons has become associated with national pride, independence, technological prowess and the ‘masculine’ ability to punch above one’s weight”. She argues that the high value of nuclear weapon possession, domestically and internationally, is persisted by states that refuse to give up their arsenals – the five NWS – and by the countries outside the NPT that have come to gain acceptance as nuclear-armed states – India, Israel and Pakistan. While she attributes the normative contradictions and structural weaknesses of the NPT to its biography, she also acknowledges the successes of the NPT in building norms and rules which have served to slow proliferation. She describes the NPT regime as “dysfunctional” (p435) with “multiple, deep and persistent” problems (p436), blaming primarily the divergence of norms regarding nuclear weapons possession for this situation.

The significance of disarmament in relation to international norms is made emphatic here, with Johnson remarking that “non-proliferation is unsustainable without significant progress towards reducing the value attached to nuclear weapons” (p 442). This notion of double standards and therefore diverging norms is reinforced by many other authors (eg. Perkovich, 2006; Harrington, 2011). A further point is highlighted by Boutin (2011, p352) who argues that the centrality of the United Sates in the regime means that its approach and the continued significance it attaches to nukes can undermine the norms and thus the basis for regime support. This reflects that a norm need not necessarily be developed through consensus: a single player, if powerful enough, can create a norm, or at least an accepted standard. This shall be discussed in more detail in the next section. For now, we shall turn to a different and more specific aspect of norms.

The concept of prestige is an oft mentioned, but rarely thoroughly discussed, motivator of nuclear policy, and particularly so in not only nuclear weapon development and acquisition but also in retention of nuclear arsenals. Intuitively, it seems obvious that demand for nuclear weapons will continue so long as their possessors continue to “flaunt them as emblems of great power” (Perkovich, 2006 p357). O’Neil (2006, p2) argues that building and testing nuclear weapons bears prestige since there are clear borders between success and failure, it is salient and symbolically powerful. Thus prestige is considered “strategically useful and sought after” and although O’Neil argues for the importance of higher-order beliefs (p28) he also makes emphatic that empirical tests must be based on behaviour rather than words or cognates of leaders.

The argument for the role of norms in both cases of proliferation and non-proliferation is quite persuasive. Lynne-Jones (2010, p.xiii) summarises this:

> “If nuclear weapons are seen as legitimate weapons that confer status and prestige on states that possess them, states may be more likely to seek them. On the other hand, if nuclear weapons are regarded as illegitimate and there is a strong norm against acquiring them, fewer states are likely to pursue the nuclear option. Many observers believe that the NPT has encouraged the development of a strong international norm against acquisition of nuclear weapons.”

Since there appears to be a choice of norms however – states can either pursue a norm of proliferation or non-proliferation – the theory of norms is clearly lacking somewhat. It would seem, therefore, that this theory must be considered as part of the wider literature on nuclear policy making.

External incentives: interact with domestic factors

The role of external incentives in proliferation decisions has not been developed into a specific theory or model and until recently lacked empirical enquiry and serious validation. However there are a number of factors which are considered to be of vital significance to the discussion at hand and thus worth reviewing. The first is the role of the United States in world affairs.

The role of the United States in matters of proliferation cannot be emphasised enough. In the Cold War period, the foreign policies of both the US and the Soviet Union were by and large premised upon nuclear matters and necessarily shaped the nuclear field we are faced with today. Post Cold War, US policy has dominated international interactions. The US does contribute enormously to the development of norms; however its own influence extends beyond and almost independently of these norms. In typical “do as I say, not as I do” style, the US exerts huge pressures on states to follow the path of non-proliferation despite their own attachment to nuclear weapons. Levite (2002/03, p76) acknowledges the “glaring omission” in the literature of a “systematic assessment of the vast array of non-proliferation instruments and assets employed by the United States across the cases of nuclear restraint and reversal”, mounting a convincing argument36 based on the claim that “an understanding with the United States is, in fact, a hallmark of many cases of nuclear slowdown or reversal” (p82). She contends that the US is least influential in effecting the nature of domestic regimes which shape nuclear ambitions, concluding that “success is within reach only to the extent that foreign influence and domestic conditions converge, and the foreign effort is closely tuned (in terms of both agenda and timing) to the domestic context” (p87). While the mechanisms by which the US asserts its influence are many and varied37, the hegemon’s role in non-proliferation is deemed to be fundamental.

Following on from this, since the US has been so willing to “purchase” non-proliferation through various means perhaps this leads states to making small developments towards the nuclear end which they can then “sell” in order to enhance their economic or diplomatic standing. Japan and North Korea have been implicated in such actions, and it is certainly a notion worth some consideration. It is also possible that Israel’s unwillingness to admit its own nuclear status is in part that doing so may compromise its foreign aid flows, particularly from the US.

The second and related issue of vital significance is the role of sanctions, both positive and negative, in non-proliferation measures. While such actions are inextricably linked with US policy and superpower, the theoretical grounding is markedly different. Quite fortunately for the purpose of this discussion, the very recent publishing of the book ‘Sanctions, Statecraft, and Nuclear Proliferation’ edited by Solingen (2012) addresses this very subject. While the authors focus largely on specific causal mechanisms, domestic distributional costs and benefits remain at the forefront and provide insight as to how sanctions and inducements, either targeted or comprehensive, can actually have unintended consequences, particularly given varying domestic political economy models and regime types.

As noted by Stein (2012, p30) although “sanctions are as old as antiquity”, they are more prevalent now than ever, but “ironically, sanctions can weaken a state absolutely

[36] See Levite, 2002/03 p75-85

[37] Levite (p77) notes that US non-proliferation efforts have employed many unilateral, bilateral, trilateral and multilateral instruments (from dialogues and treaties to supplier regimes); softer mechanisms (norms and rewards) and more coercive ones; and universal as well as case specific means

but also strengthen it relatively (to its society and domestic opposition)" (p55). That is, sanctions may actually support the regime which is driving a nuclear program and thereby strengthen its support – a counterproductive action by any standards. Similarly, Kreps and Pasha argue that military threats may make "good politics" domestically (p175), but empirically support the hypothesis that "military threats reinforce the coalitions that are hostile to international economic integration and cooperation with international regimes more generally" (p208) – the very regimes which Solingen argues are most likely to nuclearise.

Tying in with the initial point of discussion in this section, Nincic (2012) rethinks the US counter proliferation policy with regard to inducements, intuitively noting that "few measures could be fully effective when not initiated, or at least supported, by the world's sole superpower" (p127). Observing the "abysmal failure and frequently counterproductive character of threats and punishment" (p153), Nincic pushes the role of positive engagement in non-proliferation measures. In a less US-centric rationale, Drezner (2012) claims "that more comprehensive economic sanctions – or more wide ranging inducements – will often be more likely to lead to the desired policy changes" than 'smart sanctions' which are specifically targeted to reduce externalities (p155).

The consistent failure of sanctions to procure desired outcomes is a theme throughout the various chapters. Solingen concludes by outlining three factors which burden the probability that sanctions would have the desired effects in the nuclear realm (2012, p347):

1. Inward looking autocracies, being the most frequent targets of these sanctions, are also the least vulnerable to them.

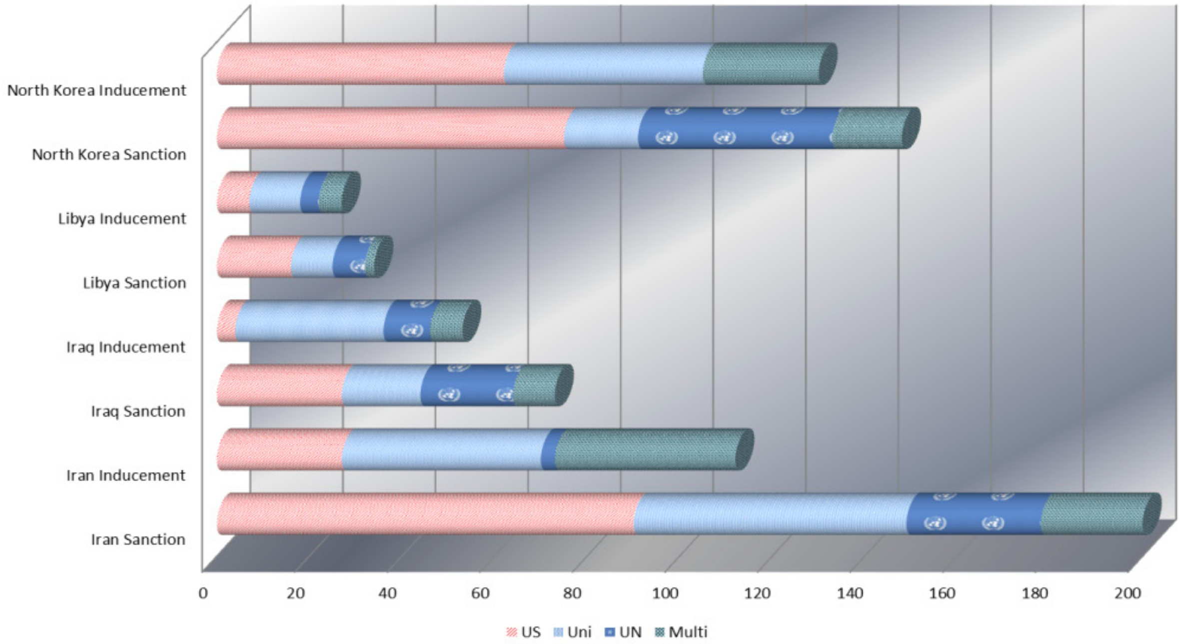
2. Selection bias results as "sanctions are expected to surface only when targets believe that concessions would risk regime survival more than defiance". That is, targets receptive to inducements may pre-empt sanctions, leaving analysis of sanctions largely on inward-looking autocracies which "appear to be endogenous to why sanctions emerge as tools of statecraft to begin with".

3. Inward looking autocracies may price nuclear weapons markedly highly, justified as public goods, making them more resistant to comply with non-proliferation demands.

To illustrate the common use of these tools, Figure 6 shows the number of sanctions and inducements directed toward the four main targets of the period 1990 to 2009: North Korea, Libya, Iraq and Iran. From this the relative use of sanctions versus inducements for each target can be recognised, as can the dominance of the US in the utilisation of these tools. Other senders depicted in the legend of the Figure are non-US unilateral (Uni), United Nations (UN), and non-UN multilateral (Multi). It is also interesting to note that 78% of sanctions in the past three decades were imposed on non-democratic target states38, which gives rise to a possibility that perhaps discriminate treatment of non-democratic regimes by more powerful nations may provide incentive for nuclear weapon acquisition by the weaker state in a struggle for power. Or in other words, economic mistreatment gives rise to a perception of threatened security, which under the assumption of realism will provide motivation for nuclear weapon acquisition.

[38] Allen (2008) cited in Drezner (2012, p155)

Figure 6. Sanctions and inducements by target-sender pairing
Source: data taken from Reynolds and Wan (2012) Tables A3.5 and A3.6



With Iran's nuclear ambitions being so enthusiastically repressed at present, a few brief points are worth mentioning – the most obvious being that the huge numbers of sanctions have not worked. Stein notes the need to create an "international sanctioning cartel"39 can often "multilateralize an initial bilateral conflict" (p41). Unilateral sanctions are often ineffective or difficult to implement on their own and thus allies in sanctioning will often be sought. Drezner (2012, p167) points out that Iran "has been under some form of embargo for its entire existence, and the regime has grown comfortable with them". Nader (2012) examines Iran in greater depth, finding it to be unclear whether sanctions have impacted Iran's willingness to pursue its nuclear program but also suggesting the nation may actually thrive on a sense of political and economic isolation stemming from its ideology (p214). He concludes: "The regime's survival is increasingly contingent on a favourable outcome regarding the nuclear program, whether it leads to a virtual or actual nuclear weapons capability. A sanctions regime contributing to Iran's economic decline cannot alter this reality." (p231)

A third point with regard to external incentives is, again, tied in tightly with the other two but worthy of mention: institutional organisations. A number of institutional non-proliferation measures have been already discussed: these include the IAEA, the UN, regional NWFZs and various other multilateral treaties. Through encouraging membership to these institutions and also utilising mechanisms under these structures, external pressure can be applied to nations in order to discourage them from developing nuclear weapons programs. The role of the US, and the use of sanctions and inducements by various nations, are both major features of any such institution, however, given the complex web of globalised trade and business patterns which have developed across the globe, the interactions of such institutions needs to be considered. While the subject of external incentives has focussed rather heavily on

[39] Stein claims that from 2001-2007 in applying one statute to prevent Iranian proliferation, the US imposed 111 sanctions against specific foreign parties; 52 were Chinese, 9 were North Korean, 8 were Syrian and 7 were Russian.

discouraging proliferation, such circumstances may exist under which external pressures act in favour of nuclearisation. Aggressive marketing by nuclear technology companies may lead a nation down the path of nuclear energy, only to find its "Siamese twin" comes too. This now leads into the supply side explanation of proliferation.

Access to nuclear technology: more able leads to more willing

This theory of nuclear proliferation is a relatively new development in the literature40 and represents the supply side, positing that a state's ability to build nuclear weapons will influence its probability of actually doing so. As nuclear technology has spread over the globe41, the technical means of developing nuclear weapons has also spread through the dual purpose nature of the technology. The technical links between civilian nuclear facilities and military programs have previously been discussed, as has the notion of a virtual nuclear state, and it is important to remember that "whether or not a state wants a nuclear weapons is irrelevant if it is unable to acquire them" (Kroenig, 2009 p163). However, as many as fifty states could be considered to be nuclear weapons capable (Hymans, 2010 p13). The puzzle then is to explain the gap between the number of states which are technically capable of developing nuclear weapons and the number which actually choose to do so. Supply side theories seem to have relied heavily on empirical analysis, and as a result some of the quantitative proliferation literature will now be introduced to this discussion.

Initially, there is a requirement that nuclear capability be defined. The possession of a nuclear reactor is obviously the first point required for a state to even be considered nuclear capable, however this is by no means sufficient. Contemporary literature has built on Meyer's (1984) landmark book 'The Dynamics of Nuclear Proliferation' and Stoll's (1996) revision of this data (cited in Sagan, 2011 p228). In defining nuclear latency, Meyer measured ten technical and economic indicators – previous national mining activity, indigenous uranium deposits, metallurgists, steel production, construction work force, chemical engineers, nitric acid production, electrical production capacity, nuclear engineers, physicists, chemists and explosives and electronics specialists42. As neither the quantity or quality of a state's nuclear engineers nor its explosives and electronics specialists could be accurately determined as being sufficient to develop a nuclear weapon, Meyer used two proxy indicators: whether the state had been operating a research reactor for three reactor years and whether the state manufactured automobiles, or assembled automobiles and manufactured radios and television sets. Based on these indicators, Meyer concluded that 34 states had the latent capability of building nuclear weapons in 1982 (cited in Sagan, 2011 p229).

Stoll's (1996) revision of the data set assumed that all states had access to nuclear materials since they were (purportedly) available on the open market, and thus "assumed away the crucial technical bottleneck of whether a state has access to uranium that, once enriched, could be used in a nuclear weapons program" (Sagan, 2011 p229). Stoll's updated data set led to the conclusion that 48 states had latent weapons capability in 1992.

Real world events brought supply side issues to the forefront of the proliferation debate and the 9/11 attack on the United States highlighted the potential role of non-

[40] Although earlier claims that having the technology would pull countries toward the bomb (eg. Quester, 1977) there was no explicit theory outlining this concept.
[41] See Appendix C for current and future states using nuclear electricity.
[42] http://es.rice.edu/projects/Poli378/Nuclear/Proliferation/model.html

state actors in international conflict. Furthermore, the uncovering of the AQ Khan network of supplying nuclear equipment and knowledge, and the apparent nuclearisation of North Korea (more on these later) demonstrated that supply chains of nuclear material and technology were out of control, and the notion of second tier proliferation became a subject for debate. Braun and Chyba (2004) point to three challenges to the non-proliferation regime:

i. Latent proliferation under the Non-proliferation Treaty

ii. First tier nuclear proliferation, in which technology or material is stolen from private companies or state nuclear programs assists non-nuclear weapon states develop illegal programs

iii. Second tier proliferation in which states in the developing world with varying technical capabilities trade amongst themselves to bolster one another's nuclear and strategic weapons efforts

They explore the proliferation "ring" formed by strategic alliances and trade occurring between and among a list of nations, most notably Pakistan, North Korea, Libya, Iran and Iraq. This inspired a greater focus on the supply of nuclear technology globally and more pertinently, the need to better understand the relationship between access to nuclear technology and materials, and weapons proliferation itself.

Data coding applied to proliferation studies were further developed by Jo and Gartzke (2007), who considered the determinants of nuclear proliferation in terms of opportunity and willingness (p168). On the supply-side, they further organised opportunity into three categories (p169): the set of technologies related to the manufacture of nuclear weapons, nuclear fissile materials, and economic capacity. They then devised three variables upon which to base their analysis (Jo and Gartzke, 2007 p172-3). First, latent nuclear weapons production capability was constructed by summing resource and production capacities using seven components: uranium deposits, metallurgists, chemical engineers, and nuclear engineers/physicists/chemists, electronic/explosive specialists, nitric acid production capacity, and electricity production capacity. Second, economic capacity was constructed using data relating to states' energy consumption and iron/steel production. Third, diffusion of knowledge of how to build nuclear weapons was assumed to occur, and quantified using a log transformation of years passed since 1938. The dependent variables were dichotomous and coded annually: NWEAPON identified whether states had a nuclear weapon in the given year, and NPROGRAM a nuclear weapons program.

In relation to nuclear proliferation opportunity, they found that latent nuclear production capabilities increased the predicted probability of having a weapons program, but did not impact the conditional decision to produce weapons. Furthermore they concluded that barriers to proliferation ease with the diffusion of time. This data set was a significant step in the quantitative approach to proliferation studies and is very widely cited, thus warrants discussion here despite doing little to actually define nuclear latency. Their measure of nuclear latency was a simple scale from zero to seven reflecting the seven components of the index. Sagan (2011, p229) is quite critical of Jo and Gartzke's coding, claiming the failure to treat possession of fissile materials as necessary for nuclear capability as inadequate. The shortcomings of their coding rules are evidenced by the fact that North Korea and South Africa are both considered to not have full capability to develop weapons in 2001[43] (ibid).

More recently, the supply side proliferation literature has explored the relationship between civilian nuclear assistance and nuclear proliferation. Matthew Fuhrmann has contributed enormously to the proliferation literature to this end[44]. He explored the determinants of dual-use trade (2008), defining dual-use commodities as having two applications: "they can be used in weapons of mass destruction (WMD) programs but also have many legitimate civilian applications" (p634). With most governments placing restrictions on the export of such commodities he was able to analyse licensed dual-use exports from the US between 1991 and 2001 (post Cold War era). He concludes his research to be "preliminary support for the assertion that states channel dual-use trade towards destinations where security guarantees exist and away from targets where security threats are present to minimise its potentially negative security externalities" [45](p648). Following from this, Fuhrmann (2009a) explores whether the diffusion of knowledge makes proliferation more likely and further examines the determinants of civilian nuclear cooperation (2009b). These works tie in with the research of Matthew Kroenig, another significant contributor on the topic of nuclear assistance.

Kroenig (2009) empirically investigates whether international sensitive nuclear assistance[46] contributes to the spread of nuclear weapons. This builds on his previous work which examines the causes of international nuclear assistance. Based on the assumption that weapons proliferation is more threatening to relatively powerful states than to relatively weak states, he find three strategic conditions under which states are more likely to provide sensitive nuclear assistance. The more powerful the state is relative to the potential recipient the less likely it is to provide assistance; states are more likely to assist other states with which they share a common enemy; and states less vulnerable to superpower pressure are more likely to provide assistance (cited in Kroenig, 2009 p164). His analysis supports the argument that states which receive sensitive nuclear assistance are more likely to acquire nuclear weapons than those which do not, and he argues that "the scholarly study of nuclear proliferation should place less emphasis on understanding which states want nuclear weapons and focus greater analytical attention on examining which states can produce them" (p176).

Where Kroenig focuses on sensitive nuclear assistance, Fuhrmann (2009a) goes even further, claiming that "all types of civilian nuclear assistance raise the risks of proliferation. Peaceful nuclear cooperation and proliferation are causally connected because of the dual-use nature of technology and know-how" (p8). He develops an original data set based on the coding of all nuclear cooperation agreements (NCAs)[47] signed from 1945 through to 2000, which is the same time period used by Kroenig, however Kroenig focuses only on the subset of sensitive nuclear assistance. Fuhrmann (2009a, p39) finds empirical support for his claim that "civilian assistance and weapons proliferation are linked because the former leads to the supply of technology

[43] When North Korea's first nuclear weapons test was only 5 years away, and South Africa had built six nuclear weapons in the 1980s and still possessed HEU.
[44] For a full list of his research see his website http://people.tamu.edu/~mfuhrmann/
[45] Draws on the work by Gowa and Mansfield (1993), Gowa (1994), Mansfield and Bronson (1997), Long (2003) (cited in Fuhrmann, 2008 p634).
[46] He defines sensitive nuclear assistance as "the international transfer of the key material and technologies necessary for the construction of a nuclear weapons arsenal to a nonnuclear weapon state" (p177).
[47] Of which there are over 2000.

and materials that have applications for nuclear energy and nuclear weapons" as well as establishing an indigenous base of nuclear knowledge. These links then reduce the expected costs of developing nuclear weapons and therefore make states more likely to begin such a campaign. This leads him to subsequently make the somewhat disturbing assertion "that "atoms for peace" policies have, on average, facilitated – not constrained – nuclear proliferation. Atoms for peace become atoms for war". (p40)
Extending these ideas, Fuhrmann (2009b) builds on his earlier work investigating the determinants of civilian nuclear cooperation. Noting the "dual-use dilemma creates uncertainty about the end-use of assistance" (p183), Fuhrmann finds that actually strategic interests are more important than limiting the spread of nuclear weapons to supplier states and argues that in some instances "some risks are accepted because atomic assistance is a potentially effective instrument of statecraft" (p186) being helpful to the recipient's economic growth and a relationship building tool. In conclusion to his empirical analysis, Fuhrmann makes the somewhat contradictory statement that "States that are exploring nuclear weapons are actually more likely to receive civilian nuclear assistance" (p202) which brings to light the recurring question of causality, or the chicken and the egg problem. Does the nuclear weapons program induce the nuclear assistance or vice versa?

Fuhrmann argues emphatically that the assistance is the precursor, however this claim is certainly refutable48. Some authors argue outright that "capability alone will not determine whether a country will make the leap from peaceful uses of nuclear energy to nuclear weapons" (Varrall, 2012 p127). Many concur that capability is necessary but not sufficient. On the flipside, Hymans (2011a) completely refutes these claims countering that "the literature needs to abandon its outdated, oversimplified, techno-centric approach to the supply side of the proliferation equation" (p101). While recognising that the aggressive spread of nuclear technologies as occurred during the 1950s and 1960s lacked concern for non-proliferation (p76), he argues that identifying that technical capacity (the independent variable on which supply analyses are centred) is "highly dependent on political variables" (p77) changes the effects which the data claims to support. Using a case study of Yugoslavia, he goes so far as to claim "Atoms for Peace can substantially retard or even reverse the growth of technical capacity to build the bomb, despite the transfer of hardware and know-how that it promotes" (p101) since civil nuclear cooperation can forge international linkages which complicate the state's ability to motivate its top scientists and engineers to dedicate the time required for bomb development to a covert and internationally opposed project (p77) and facilitate "brain drain" whereby international assistance programs ultimately result in the poaching of developing country talent to developed countries and thereby reducing the nuclear weapons capacity (p80).

At the outset, given that many countries which could develop nuclear weapons with relative ease have not, it would seem unlikely that supply side explanations of nuclear proliferation can satisfy the requirements of a good theory. But, the notion of nuclear hedging49 does bring to light the issues of not recognising the significance of supply side factors in proliferation.

Proliferation in summary

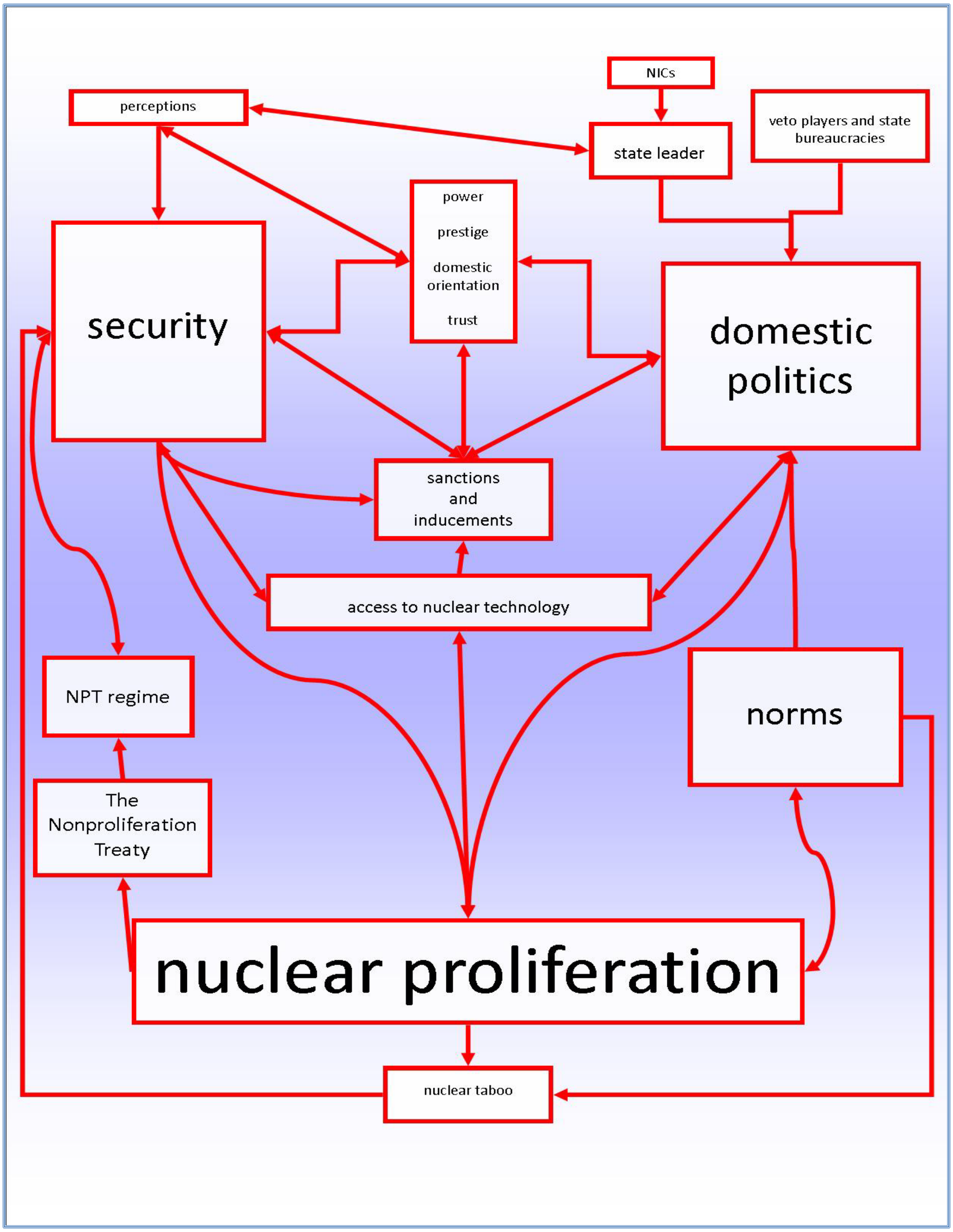
Various approaches to, and aspects of, nuclear proliferation have been discussed in this section. Common themes throughout the literature can be identified. While it

[48] For a concise critique of both Fuhrmann and Kroenig's empirical finding see Montgomery andand Sagan (2009, p315).
[49] Nuclear hedging is defined by Levite (2002/03, p59) as "a national strategy lying between nuclear pursuit and nuclear rollback".

would be both impossible and undesirable to integrate these different theories and perspectives, we can think of this information and these ideas as helping piece together the puzzle of nuclear proliferation.

As a way of relating the different theories and perspectives of proliferation, Figure 7 shows my own attempt at representing the relationships between various effectors of nuclear proliferation. These linkages have been discussed throughout this section; however the extent of these inter-relationships is highlighted diagrammatically. This iterates the need for proliferation considerations to take a wide and inclusive approach to the topic.

Figure 7 Relationships between different aspects of proliferation theories and institutions.



3. The NPT Regime and Nuclear Apartheid: Part I

What the NPT actually is was outlined in chapter two along with the Articles which make up its structure, and these have been mentioned throughout. Also stated was that there are currently 189 signatories. However, this does not reflect the history of the Treaty. Not all current parties to the treaty signed upon inception; signatories have been gathered along the way. For example, France and China did not accede to the NPT until 1992 and Brazil not until 1998.

The history of nuclear proliferation shall now be briefly covered state by state, beginning with very first instance of nuclear power and tracing it from there right across the globe.

Nuclear weapons states – the "haves" who just keep on having

The official nuclear weapon states as defined by the NPT were those which had openly tested nuclear devices at the time of signing the Treaty in 1968. As has already been mentioned, there are five such countries: the United States, Russia (formerly the Soviet Union), the United Kingdom, France and China. Each of these nations retains nuclear weapons in their arsenals to this day, and in fact weapon development continues. How and why each of these countries came to include nuclear weapons in their military arsenals shall now be briefly recounted along with purported reasons for their resistance to giving up these weapons.

The United States

Despite the fact that nuclear fission had been discovered in Berlin in 1938[50], the US became the hub for nuclear physics advancements. As the political climate in Europe descended, many great thinkers and philosophers fled the Continent to escape risk of persecution, with many of them ending up in the safe haven of the United States. Albert Einstein had already settled in the US in the early 1930s and had sparked FDR's decision to develop a nuclear program (Reed and Stillman, 2009 p8). Despite this displacement of many academics from Europe, news of the discovery that nuclear fission was more than a theoretical possibility spread quickly throughout the world with the German physicist Otto Hahn publicly publishing his findings at the end of 1938.

Mahaffey (2009, p99) describes 1939 as the "ignition point in the race for the atomic bomb". As ideas of nuclear weaponry swept across the increasingly unstable world, nations devoted huge amounts of resources to realising these aspirations. Germany, in fact, had a very active and somewhat progressive nuclear weapons program. However, advances were severely hindered by the separation of physics into Jewish physics and Aryan physics and the subsequent disregard for Jewish physics, which involved philosophies such as relativity and quantum mechanics. Mahaffey (2009, p105) poignantly notes; "A country that prided itself for technical superiority and innovation stopped its forward motion at the most exciting and important point in the history of science, on pseudo-religious grounds". As fleeing geniuses brought with them news of a German bomb program, however, the United States ramped up its efforts and instigated a "crash" program.

Equipped with some of the world's most brilliant minds[51], ample resources, and a hungry desire to beat Hitler to the bomb, the Los Alamos Laboratory in the United States made rapid progress in the quest for nuclear weaponry. Equally as significant as science in the path to nuclear superiority were the epic achievements of American industry in supplying the essential materials needed for the weapons (Reed and Stillman, 2009 p16). An enrichment facility began producing weapons grade enriched uranium in merely two years after commencement of construction; a larger plutonium

[50] Otto Hahn and Lise Meitner initiated this work, however Meitner was forced to flee Germany, ending up in Sweden and only received recognition for her work years later.
[51] For a summary of these great minds, see Mahaffey 2009 (p 106).

producing reactor and reprocessing facilities were built after Fermi's pile[52] went critical and proved the theory of a nuclear chain reaction. And similarly, the achievement to get the technology to the weapon stage was equally as remarkable. The world's first atomic weapon was built in an unbeaten time of ten months from reactor to bomb. The crash program of the United States had been a success; an atomic bomb was tested on July 16, 1945 in New Mexico. The nuclear age had dawned.

America's motives in using the bomb against Japan have been questioned by many[53], and are beyond the scope of this study, however the bombing of Hiroshima on August 6 1945 and Nagasaki two days later sent a clear and poignant message to the world: the United States was officially the first nuclear weapon armed nation, and they were willing to use it. The utter destruction rendered over these Japanese cities signalled the military supremacy of the US and Japan quickly surrendered[54]. The devastation caused still lingers in people's minds and is a constant theme in disarmament movements.

Despite America's best intentions and efforts to keep the technical knowledge for the development of such a device a national secret, the multicultural makeup of the Los Alamos squad which had driven such rapid development also ensured that this knowledge was not strictly American. At the exact time that nuclear weapons became a reality, the threat of nuclear proliferation also became a reality.

The spread shall be discussed on a country by country basis, however America's attachment to the bomb (or bombs rather, since the US is estimated to possess around 2150 nuclear armed warheads![55]) has undoubtedly consolidated the links between national power and prestige and nuclear weapons. McCgwire (2005, p 119) argues that the US "has not changed its mind since 1946 about the positive benefits of nuclear weapons" and in negating its own NPT responsibilities has allowed cynics to accuse the NPT as having become a "convenient instrument of US foreign policy" (p120). The current US President, Barrack Obama, is the first American leader to have spoken seriously about the possibility of US disarmament; prior talks had been mere lip service, and without serious commitments to this end from the world's largest possessor of nuclear weapons any disarmament efforts are futile. It has been much to the disgust of the NNWS that despite the end of the Cold War, the US continues to use/abuse its status as the sole nuclear superpower. Since 9/11 America has relied heavily on security explanations of its retention of and reliance on nuclear weapons for matters of national defence. Whether this is an accurate claim is quite a debatable issue and would go a long way to helping the non-proliferation regime. However, while America continues to support a nuclear arsenal but refuses to support a "no first use" policy the true intentions of US nuclear policy will be disputed[56].

The Soviet Union

Indigenous Soviet nuclear physics existed in pre-war times, with ideas of an atomic bomb set forth by Soviet scientists in 1939 but the focus required to fight the war

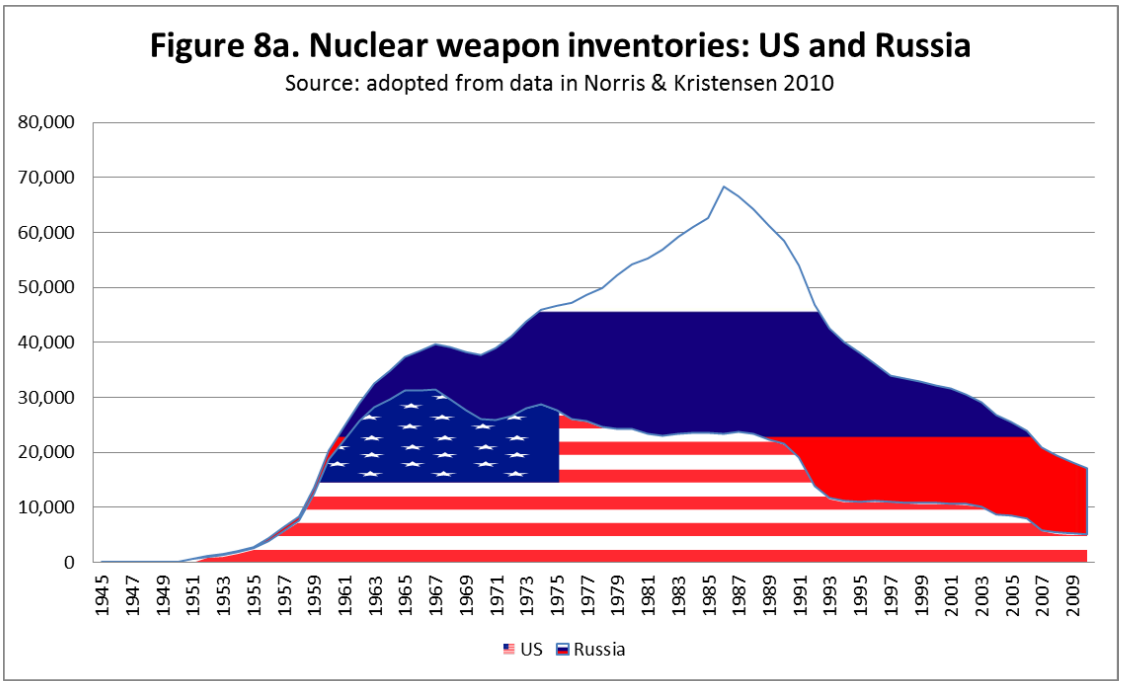
[52] Fermi's pile, formally known as Chicago Pile One or CP-1 was the world's first self-sustaining nuclear chain reaction which was built in unused squash courts at the University of Chicago.
[53] While many accept the US needed to use the bomb to force Japan to surrender some have labelled this as neglecting many points. For more on this see McWilliams and Piorowski 2009 p 17.
[54] Also debatable as to whether the bombs were the decisive point in Japans surrender.
[55] From Kristensen and Norris 2011b.
[56] For example, Chomsky.

prevented full development in this area57. Therefore when World War II came to an end and the US had openly demonstrated their superiority with the possession of the ultimate weapon, the Soviets had some serious catching up to do. The excellence of the Soviets in matters of espionage, however, meant that they were collecting up to date information from the heart of Los Alamos with three significant, and now well known, spies (also brilliant scientists) in labs there; Klaus Fuchs, Ted Hall and David Greenglass (Mahaffey, 2009 p203). While a fuller discussion of the Soviet spy trade would be interesting, it is sufficient to note that the Soviet nuclear program relied very heavily on flows of information from outside the Soviet Union.

With the benefit of also learning from the mistakes made within the American project, the Soviets were able to catch up with relative ease, building their own Fermi's Pile in 1946 and developing a Los Alamos equivalent; the facility was referred to as Arzamas-16. The development of atomic weaponry was deemed nationally significant, and thus adequately resourced for rapid progress. By 1949 the facility had developed a device ready for testing; this was conducted on August 29 at Semipalatinsk, Kazakhstan and deemed a success. Thus the Soviet Union had risen to nuclear power in much less time than the US or anyone else had expected. The first instance of nuclear proliferation had been realised, emphasising the unlikelihood of containing the technology from further spreading.

The cases of the United States and the Soviet Union represent a special scenario in the story of nuclear proliferation, being the rival superpowers at the forefront of the Cold War. These two nations demonstrated that vertical proliferation was a further issue in the nuclear story, as the arsenals of each nation expanded rapidly to such levels that each could destroy the other many times over. While horizontal proliferation niggled away over the coming years, exponential vertical proliferation in the form of the arms race heightened tensions of nuclear warfare and threw nuclear issues into the centre of world politics. Figure 8a shows the growth in the number of US and Russian nuclear weapons post WWII, with their combined total peaking at nearly 70,000 weapons. US Secretary of Defence, Robert McNamara admitted a nuclear arsenal of 400 megatons was enough to ensure Mutually Assured Destruction (MAD). At that time US stockpiles amounted to 17,000 megatons (McWilliams and Piotrowski, 2009 p511).

[57] See Reed and Stillman Chapter 4 or Mahaffey p 201-203 for a more thorough discussion.



With the breakup of the Soviet Union in 1991 the Cold War came to an end. Some of the Soviet nuclear weapons ended up in the possession of the newly formed states of Belarus, Ukraine and Kazakhstan. These countries all worked with the US in renouncing these weapons and signing the NPT as NNWS (more on this later). Russia has retained a substantial arsenal in the post-Cold War world. One could argue its reasons may be similar to the US. However Russia's military presence is far less global than America's so this might support the notion that Russian nukes are genuinely a defence tool. It would be hard to imagine that status does not play a role in retention of nuclear weapons too. Soviet power has been in decline for quite some time and nuclear possession almost certainly enhances Russia's diplomatic leverage and role in global security.

The United Kingdom

With 25% of the Los Alamos staff being from the UK and Canada[58], the technical knowledge was going to be very difficult to keep within US borders. The British wartime nuclear program had been relocated to the safer grounds of Chalk River, Canada, in 1940, and once the US became actively involved in the European War many of these scientists moved to Los Alamos to become a part of the team to build the world's first A-bomb. As Prime Minister of Britain in the nuclear development stage, Winston Churchill had recognised the national significance of nuclear know-how and negotiated an information sharing agreement with US President Roosevelt. However, with the death of FDR and misplacement of the document, the alleged agreement was never recognised. When leaks into the Soviet camp were discovered to have passed through British citizens and British sponsored émigrés any hope of amicable cooperation was dismissed[59] and with America inclining back toward a policy of isolation, Britain was forced to resource its own nuclear program.

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[58] Reed and Stillman p 13.
[59] Reed and Stillman p 45.

The UK's first nuclear reactor was built at Windscale and went critical in July 1950. Five years and nine months after the decision was made to proceed with nuclear weaponry, the British tested their first nuclear device off the West Australian coast on October 3rd, 1952. In the following year the deserts of South Australia became nuclear testing grounds with eight more explosions allowing the British to refine their atomic weaponry skills and knowledge.

The UK has never used, nor seriously considered using, a nuclear weapon and now has "the smallest and least operationally active nuclear force" (Walker, 2010 p452). Why, then, does Britain persist with its nuclear card? McCgwire (2005, p 133) posits three reasons as to why Britain needs a nuclear capability: "political status; sunk costs; and come-in-handy". Pointing to the lack of clarity in Britain's nuclear policy vis-à-vis whom nuclear forces are to deter from doing what, he argues the last two represent essentially the same thing – that Britain might as well retain nukes as they already have them. He reasons "in sum, the only real reason [Britain needs nuclear weapons] is political status". O'Neill (1995, p753) supports this view, noting that both British and French political opinion still largely believe that nuclear weapons are vital to their country's status, ensuring a place at top tables globally, particularly on the UN Security Council. This is a notion which he disputes, claiming that British nuclear weapons have an insignificant role in Britain's security60 (p760). McCgwire goes on to argue that Britain has options to choose alternative roles. Being territorially, economically and militarily secure with senior membership in all major international institutions, he contends that Britain has the potential to fulfil its desired role in global affairs without the possession of nuclear weapons, and furthermore that the status in being one of the first three nuclear powers cannot be removed. Walker (2010, p462) sums up the British position:

> Although the UK seems closest to the disarmament threshold, the 'barriers to exit' from its possession of nuclear weapons remain high. Those barriers are not just connected with security: issues of prestige and identity and the weight of political and institutional commitments are also influential.

France

Although the French physicists Marie and Pierre Curie had spawned wartime nuclear advancements with their work on radioactivity early in the twentieth century, the German invasion took obvious priority and thus a serious nuclear program was not commenced by the French until after the War had ended. French President Charles de Gaulle urged French physicists working at Chalk River in Canada to return home and in 1945, very shortly after the end of the war, he created the world's first atomic energy commission. The French Atomic Energy Commission (CEA) was to develop nuclear energy for the benefit of France in matters of science, industry and national defence (Reed and Stillman, 2009 p69). De Gaulle saw the possession of atomic weaponry as essential in not only ensuring French security, but also in restoring France's credibility on the international stage. There was also serious potential to address French energy requirements as the country had no oil or coal resources. Frederic Joliot-Curie, who had been installed as the high commissioner of the CEA, was a communist whose vision was focused more on nuclear power than weapons61 and when de Gaulle lost office later in 1945 the French quest for the A-bomb was suspended.

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[60] At the time of writing in 1995

[61] Reed andStillman p69-71

By 1958 when de Gaulle returned to the French presidency, Joloit-Curie had been replaced by Francis Perrin and the first French reactor had been online for over two and half years. Colonial troubles in Vietnam and Algeria of the early 1950s had led then President Pierre Mendes-France to decide that an A-bomb should be researched, enabling de Gaulle to harness this latent capacity and quickly authorise that a nuclear test should be conducted within two years. Despite the offers from the United States to station nuclear weapons in France, de Gaulle's desire to restore France's prestige led him to forge ahead with his own force de frappe or 'strike force' (McWilliams and Piotrowski, 2009 p84). On February 13, 1960 France detonated their first A-bomb in the Sahara Desert, Algeria and thus became the fourth entrant to the nuclear club.

So what explains the nuclear choices of the French? Perkovich (1998, p16) claims that, like Britain, factors beyond security drove France to develop its nuclear arsenal, cleverly arguing that "irrelevance is the only "clear and present danger" against which France's nuclear weapons defend" as nuclear status will preserve the permanent seat on the Security Council. France still relies heavily on its nuclear arsenal for matters of deterrence. Some have "declared that France's new nuclear strategy – including the acquisition of weapons with greater range, accuracy and flexibility – amounts to an affirmation of the utility of nuclear weapons and therefore contradicts efforts to downgrade their importance and promote nuclear non-proliferation and disarmament" while others note "that proliferation confirms France's resolution to maintain its nuclear force" (Yost, 2006 p715-16). With France producing over three quarters of its electricity using nuclear energy it seems unlikely that nuclear weapons would not feature heavily in other aspects of national policy.

China

The overthrowing of the Qing Dynasty in 1911 saw the end of over four centuries of isolation, and with that the importation of Western ideas. Reed and Stillman note "the real acquisition of Western knowledge was accomplished one graduate student at a time" and point out that a number of the leaders of China's nuclear program were educated in Western universities, mainly in the US (2009, p87-88). The 'father of China's A-bomb program', Qian Sanqiang, was a former student of Frederic Joliot-Curie in Paris and received assistance in the form of instruments and knowledge from both him and Irene (p91).

The post WWII period was not a stable time for Asia, and particularly China. With battlegrounds in Korea and Vietnam and ongoing tensions with India and the Soviet Union, the Chinese desire for weapons of deterrence intensified. Nuclear threats had been made against China by the United States62, and discussions between the Soviets and China promised the sharing of some civilian nuclear information. The US support for Taiwan in the 1954 US-Taiwan Mutual Defence Treaty was instrumental in Mao's final decision to go nuclear and in 1955 he authorised the development of a Chinese nuclear bomb (Reed and Stillman, 2009 p93).

Over the coming years, the Soviet Union gave a great deal of assistance to China, helping them develop their own nuclear program. Of course, the priority of bomb development was masked by China's proclaimed desire for peaceful applications of nuclear energy. As Sino-Soviet relations deteriorated later in the 1950s and the Soviets finally withdrew in 1959, the nuclear weapons program slowed somewhat. However, through careful planning and meticulous execution the secret program forged on and

[62] Reed and Stillman describe these threats as understandable since there was no other feasible option against an enemy of such size with a tolerance for massive casualties

finally tested its first device on January 15, 1955. The fifth and final official nuclear power had been declared.

Although Chinese engagement with the non-proliferation regime was initially reluctant, this was more a reflection of its wariness toward multilateralism more generally (Boutin, 2011). Additionally, China was suspected of assisting the Pakistani nuclear program (for example Boutin, 2011; Jacob, 2010). However, over time China "shifted from being 'part of the problem' to 'part of the solution'" (Chu and Rong cited in Boutin, 2011 p354) supporting the regime, publicly adopting a "no first use" policy and emerging as a fervent supporter of the institutional pillars of the regime (p359). Chinese acquisition and retention of the bomb can thus be best understood as a security measure which was initially designed to counter Western threats and continues on in national strategy to assist in matters of border conflicts and territorial disputes.

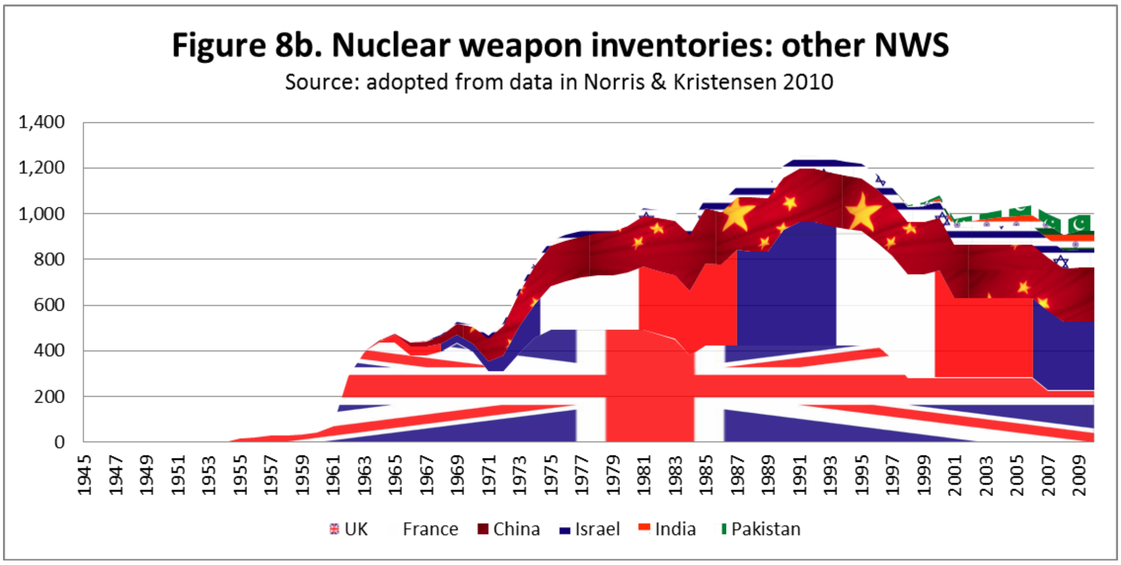

Figure 8b. Nuclear weapon inventories: other NWS

Source: adopted from data in Norris & Kristensen 2010

Figure 8b traces the nuclear inventories over time of the NWS other than the superpowers, as well as Israel, India and Pakistan. Whilst horizontal proliferation has, as mentioned, been of considerable concern, in comparing Figure 8a and 8b, note that the combined total arsenals of all other nuclear weapon states does not compare with stocks accumulated by either the US or Russia alone.

4. The NPT and Nuclear Apartheid: Part II

Non- signatories – the "really shouldn't have" nuclear weapon states

These states lie outside the confines of the NPT, therefore the rules do not apply to them. They have nuclear weapons, but as these states are not party to the Treaty there is nothing wrong per se. Their absence from the Treaty, however, undermines the global application of the rules and norms instituted by the regime and therefore threaten its legitimacy. Former IAEA director general Mohammed Elbaradei makes the point that they cannot enter the Treaty through the front door as from their point of view their security situation does not allow them to enter the treaty as NNWS. Not attempting to draw them in is not in line with the aim of the Treaty, which is a world free of nuclear weapons. For these reasons the non-signatories remain outside of the

Treaty enforcement framework and outside the scope of international safeguards. Of these four nations, Israel, India and Pakistan refused the Treaty from the outset while North Korea withdrew its membership.

Israel

The case of Israel presents a unique case in that Israel has never actually tested a nuclear device, and is therefore very much an undeclared nuclear weapons state; this has been coined by many authors as nuclear opacity63 (Abraham, 2006) refers to the deliberate strategy of uncertainty. Also generally conceded in the literature are the close ties between the French and Israeli nuclear programs, with comments such as "some wags have noted that on Feb 13, 1960, two nations went nuclear with one test" (Reed and Stillman, 2009 p79). Israel had begun its own nuclear program in the wake of independence in 1949, with recent memories of the Holocaust being spurred by unrest with its neighbours. The Suez Crisis of 1956 firmly aligned the interests of Israel and France by uniting them against a common enemy: Egypt.

While the extent of French assistance in the Israeli nuclear program is open to debate, it is suffice to acknowledge that there was indeed collaboration (for example Reed and Stillman, 2009; Maoz, 2003; Solingen 2007). As Israel's nuclear weapons program has never been officially acknowledged, all nuclear activities to date have been labelled incessantly as peaceful scientific/industrial developments. By 1963, however, Israel's first production reactor at Dimona went critical and as the nature of the program came under suspicion, inspection charades kept the true nature of the program concealed64.

What also makes this case unique is that Israel is a one bomb nation state. That is, the entire nation could be destroyed with one decent sized thermonuclear weapon. Such an event could only be described as a second Holocaust, the possibility of which is an extremely emotional and politically charged issue; "Israel, therefore, has virtually no margin of error" (Rosenbaum, 2011 p134). That Israel simply cannot risk nuclear warfare only serves to highlight the precision with which it has handled not only its own nuclear policy, but that of its neighbours. The Six Day War of 1967 demonstrated Israel's determination to hold its position when it conducted a hugely successful pre-emptive strike on Egypt before moving troops into Syria and Jordan. Some consider that Israel's possession of nuclear weapons at this point in time gave it the confidence to take drastic action such as this (eg. Reed and Stillman). In 1981 Israeli Air Force F-16s terminated the Iraqi nuclear reactor at Osirak near Baghdad, which was capable of producing weapons grade plutonium, on the grounds of defence. In 2007 an airstrike took out Syrian nuclear facilities, and today defence analysts across the globe speculate as to whether or not Israel will launch a pre-emptive strike against Iran's alleged weapons facilities.

Rosenbaum (2011, p132-165) repeatedly points to Israeli fears of a second Holocaust being initiated by any one of its hostile neighbours, and implicates its reliance on the being the sole possessor of nuclear weaponry in the region as its most effective form of deterrence. He also makes a rather grave prediction that sooner or later Israel will unleash nuclear weapons in preventative action (p140). Maoz (2003, p48) is more positive arguing that "Israel's nuclear policy has essentially accomplished its principal

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[63] Opacity as defined by the Oxford dictionary **1** the state of being opaque or difficult to see through. **2** the quality of being difficult to understand.

[64] For a discussion on both French assistance and inspections of Israeli facilities see Stillman and Reed Chpt 6 and p 117 - 121

aim: shifting the strategic objectives of Arab states to reflect a growing awareness of the futility of trying to destroy Israel".

So can Israel's nuclear decisions be traced primarily to security? Not really. Maoz (2003, p52) argues that "just as Israel's nuclear project was taking a military turn in the early 1960s, the gravity of the threat it was supposed to address had significantly receded" suggesting that other forces were at play in this case. He also points to a significant discrepancy between the stated aims of Israel's nuclear policy and the quantity and types of weapons produced. Maoz (2003, p71) claims this could only be the result of a shift from deterrence oriented policy to more offensively oriented policy, or that "technological considerations and bureaucratic inertia, rather than an overarching strategic logic" have driven Israel's nuclear program.

Solingen (2007, p187-212) considers that if Israel's nuclear policy was a straightforward case of state survival that they should have declared their status and that balance of power theory in the case of Israel offers a wide range of outcomes. She argues that ambiguity assisted domestic equilibrium, prevented a "political big-bang" and facilitated compromise while allowing some modus vivendi among divergent interests (p210). Other authors bring a new perspective on US involvement in the Middle East suggesting strong Israeli ties to US policy making (eg. Mearsheimerand Walt, 2006), an issue which has already been touched on.

While a fuller discussion of the merits of Israel's nuclear program is beyond the scope of this paper, it is important to acknowledge that generally the possession of nuclear weapons is accepted to have enhanced Israel's security position somewhat. On the other hand, and to complicate matters further, Israel's possession of nuclear weapons is often considered to have driven its Middle Eastern neighbours to seek weapons themselves.

India

India's development of nuclear weaponry was long and turbulent. Although an atomic energy institute was first established in 1945, weapons were not on its agenda until the Chinese nuclear test in 1964. This represented an insulting show of power by its northern neighbour who had embarrassed India two years earlier in the Sino-Indian Border War. In the period following, India sought a nuclear guarantee from the nuclear weapon states however failed to do so65. In the aftermath of the second Indo-Pakistani War in 1965 in which China had provided support to Pakistan, India officially registered its opposition to the terms of NPT, and consequently did not sign the treaty on the grounds of the lack of reciprocity between the NWS and NNWS (Ganguly, 1999 p157).

In May of 1974 India carried out its first nuclear test with the demonstration of a 'peaceful nuclear explosion'; while the test was domestically a huge success, the international reaction was markedly different with all of the major powers other than France condemning India's actions. The device, known as Smiling Buddha, used thirteen pounds of plutonium produced at the CIRUS (Canada India Research United States) "Atoms for Peace" reactor (Reed and Stillman, 2009 p237), much to the outrage of Canada and the US who promptly ceased all nuclear cooperation with India, ultimately enhancing the indigenous nuclear program (Ganguly, 1999 p159). Despite an apparent lull in Indian nuclear progression, international relations in the South Asian region took a turn for the worse with the Soviets invading Afghanistan in 1979. The result was the development of a US-Pakistan collaboration which drove India into

[65] See Ganguly 1999 p 152-155 for more on this and also Kennedy 2011

the open arms of the Soviet Union and firmly down the path of nuclear weapon acquisition.

Piecemeal progress throughout the 1980s saw slow development of the nuclear program, hindered by political instability. In 1996, however, when India announced a reversal in its long standing support for the CTBT its intentions were clear and on May the 11th 1998 India detonated three nuclear devices. With its ally the Soviet Union dissolved, India announced officially to the world that it would not be signing off as a non-nuclear weapon state in three big, simultaneous blasts.

What has not been mentioned thus far is that before nuclear apartheid was institutionalised in the NPT, India was a solid supporter and promoter of non-proliferation and disarmament. The first Indian Prime Minister, Jawaharlal Nehru, had been the first world leader to propose a nuclear test ban (Kennedy, 2011 p126) and anti-nuclear sentiments persisted after his death into the late 1960s and the lead up to the NPT. Renewed efforts in nuclear diplomacy were driven by Prime Minister Rajiv Gandhi who pushed nuclear test ban, non-proliferation and disarmament talks throughout the 1980s; by 1989 it had become apparent that these efforts had failed and thus India forged ahead with its weapons development program (Kennedy, 2011 p144-146).

So can India's nuclear trajectory be explained primarily by security implications? Some have argued that India's changing approach to nuclear weapons can be primarily understood as a function of its changing levels of security assurances through non-military means and that diplomatic pursuits are possibly reflective of economic shortcomings to such ends (Kennedy, 2011 p151-152). India, like China, has adopted a "no first use" policy, iterating that with regard to security, nuclear weapons are regarded as defence only.

A final point which is important to note is that although India cannot be granted official NWS status it seems to have many of the rights. The 2005 US-India Civil Nuclear Cooperation Initiative was endorsed by the NSG which amounts to special treatment of a non-signatory; an action which doubters of the NPT regime argue delegitimises the pillars of the Treaty.

Pakistan

Pakistan has undoubtedly been the biggest problem faced by the non-proliferation regime66. It is politically unstable and socially radical; has volatile relations with its neighbours including unsettled scores with nuclear armed but conventionally superior India; has a powerful and independent military; recently harboured the world's most wanted terrorist Osama bin Laden; and is called home by the world's most famous illicit salesman of nuclear technologies, AQ Khan. And to boot, Pakistan has the fastest growing nuclear stockpile in the world today (Kristensen and Norris, 2011a p91). Intent plus ability equals problem.

Pakistan formally announced its nuclear capabilities to the world in 1998 immediately following the Indian detonations. Ahmed (1999, p177) describes Pakistan's nuclear policy as being "India-centric, revolving around perceptions of threat from and hostility toward India" and the quick reaction to India's nuclear testing certainly suggests that this is in fact the case (see also Chakma, 2002). This "sibling rivalry" (Tkacik, 2010, p176) has defined the India-Pakistan relationship from inception. Although the Pakistan Atomic Energy Commission (PAEC) had been established in 1957, it was not

[66] Although more recently seems to have been superseded by Iran

until 1966, and after substantial nuclear advancements on the part of the Indians, that Pakistan considered nuclear weapons strategically desirable (Ahmed, 1999). By 1968, and following India's refusal to sign the NPT, Pakistan had made up its mind; nuclear weapons were necessary. Then, coupled with various defeats by the militarily and politically superior India, the 1974 Indian detonation of a peaceful nuclear explosion made acquisition of nuclear capability a national priority. A nuclear weapons program separate to PAEC was established and headed up by a metallurgic engineer who had been working in Europe by the name of Abdul Qadeer Khan.

In 2004 AQ Khan was discovered to be at the centre of a global proliferation ring which was distributing nuclear information and technology to would be proliferators in return for money and in some cases related technology such as missile designs and delivery systems67. While the Chinese are generally implicated in assisting the Pakistani nuclear program68, and the Americans turned a blind eye to it in return for Pakistani assistance in US endeavours in Afghanistan and the war on terror69, Pakistan's involvement in the spread of nuclear weaponry has been substantial. The Khan network illegally obtained equipment and designs out of Europe, and also provided assistance to North Korea and Iran, and probably Libya, Syria and Iraq (among possible others)70. The Pakistani government claims it was not involved in this "proliferation ring" (Braun and Chyba, 2004). Pakistan had also been the recipient of civilian nuclear assistance from both Canada and the US in building the Karachi Nuclear Power Plant which provided fuel from which plutonium was extracted for weapons development. The US has also provided Pakistan with tens of millions of dollars in aid money to secure its illegitimate nuclear arsenal (Kristensen andNorris, 2011a).

Furthermore, Pakistan now has a very extensive nuclear industry itself – and it's growing. Recent estimates put the Pakistani nuclear stockpile at up to 200 within ten years, which is comparable to that retained by the British (Kristensen and Norris, 2011a p94). Tkacik (2010, p 191) argues that "there is little doubt that a nuclear arms race is underway between Pakistan and India (and to a lesser extent China)" and suggests that Pakistan may be looking to cross the thermonuclear threshold. This emphasises the problem of vertical proliferation, which has been mentioned and was certainly a significant issue in Cold War times, but is less discussed than horizontal proliferation.

So, has security been the major driver in Pakistan's quest for nuclear power? One could argue that this is the case regarding the ceaseless tensions with India who has superior conventional military might and a much greater economic and demographic base. However, norm and prestige also play a role. Tkacik (2010, p188) argues that while their official nuclear doctrine has not been released, it is likely that Pakistan's nuclear doctrine focuses entirely on India, and probably have not ruled out first use.

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[67] Tkacik, 2010, claims "nuclear proliferation has allowed Pakistan to upgrade its nuclear weapons arsenal by exchanging nuclear weapons knowledge for other needed technology, such as delivery vehicles"

[68] Reed and Stillman speculate that the Chinese may have actually tested a bomb for Pakistan in May 1990,

[69] See The Economist, 2004, Mar 11, The man in the middle

[70] For a more thorough discussion see Braun and Chyba, 2004

North Korea

North Korea presents a unique case in that it is, to date, the only nation to have exercised its right under Article X of the NPT and withdrawn from the Treaty. In quite an extraordinary turn of events, North Korea became the first nation to take this road. Tensions hanging over from WWII on the Korean peninsula were exacerbated by a division between North and South; North Korea was established as the Democratic People's Republic of Korea (DPRK) and was proclaimed a Communist state71. This ultimately led to the Korean War which represented the first real battleground of the Cold War (McWilliams and Piotrowski 2009), and consolidated security as a major and permanent concern for the leader, Kim Il Sung, of the newly formed state. The Soviet backed North Korean government had completed construction of a 5MW reactor which was operational by 1967 and had been indigenously upgraded by 1974 (Reed and Stillman, 2009 p261). In 1985 DPRK joined the NPT due to contingencies imposed upon it by the Soviets in return for light water reactors which were required to help meet energy demands (Hecker, 2010 p45). North Korea has significant deposits of uranium, but is otherwise reliant on imports for energy. However, in 1987 the covert construction of a reprocessing facility began. It was clear by this time that North Korea had nuclear motives beyond a civilian program, and indeed IAEA inspectors quickly discovered discrepancies (ibid).

The crisis which ensued seemingly ended with the signing of the Agreed Framework in 1994 between the US and the DPRK in which the US guaranteed to supply LWRS and fuel in return for the cessation of Korea's nuclear program. These objectives never eventuated; some claim Pyongyang halted its plutonium program but continued expanding its missile program and exploring the alternative HEU path to the bomb (Hecker, 2010 p46) while others claim that both reactor and reprocessing facilities expanded, probably using technology supplied by AQ Khan which was then re-exported along with various other missile technology (Reed and Stillman, 2009 p261; Hecker, 2010 p47). Nonetheless, DPRK's nuclear program did continue and in 2003 it withdrew from the NPT, exploiting the "loophole" of the Treaty in that it had been acquiring nuclear technology under the auspices of refraining from proliferating. This demonstrated the reality of what many had been predicting (eg. Wohlstetter, 1976) and in October 2006 it tested its first plutonium device72, announcing its official entrance into the nuclear club73. In May 2009 DPRK's second testing of a nuclear device reiterated this status.

So what has motivated a little country like North Korea to pay the huge price involved with nuclear weapons development at the cost of its own people? Hecker (2010, p48) argues that "security concerns have been the central driver of the North Korean ruling regime since the birth of the nation after World War II" but that domestic and diplomatic factors have also been significant in shaping Korea's nuclear path. He claims that "Pyongyang does not appear to have allowed international norms to influence its nuclear decision-making" since it has defied norms and "used the power and prestige derived from the bomb as a diplomatic lever" and possibly to support domestic changes (p52). This ignores the normalisation of the duality of power and the bomb however, if one considers it normal for a powerful and prestigious state to possess the bomb then North Korea can indeed be considered to have been aspiring to this norm.

[71] The legitimacy of which was not formally recognised by many parties for quite some time.
[72] Reed and Stillman claim that the device was probably a derivative of the CHIC-4/A.Q. Khan design.
[73] The success of the test has been deemed anywhere from failure to reasonably unsuccessful due to the low yield of the device; nonetheless it did detonate a nuclear bomb.

Recent events have indicated that the nuclear policy of DPRK may be going to change. At the end of 2011 North Korea's second dictator, Kim Jong Il, died leaving his grandson Kim Jong Un at the helm of a nation in tatters, but with two significant drawcards: nuclear weapons and unambiguous support from China[74]. Defying expectations, on February 29 2012 North Korea and the US made public an agreement that Pyongyang would suspend its uranium enrichment program at the plant in Yongbyon, allow IAEA inspectors in, and impose a moratorium on the testing of weapons and long-range missiles in return for American aid and diplomatic support[75]. Then on April 13, DPRK attempted to launch a satellite using a long-range missile; the launch was a complete failure but reports suggest that they may make another attempt soon. What this means for its nuclear policy remains to be seen, with the new dictator appearing to have "inherited his father's tactical genius for passive-aggressive foreign relations"[76]; however one can only imagine that perhaps the leader of North Korea should decide that his people have already paid a high enough price for a diplomatic tool which may have reached its use by date.

Non- nuclear weapon states – the "have- nots"

There are 189 signatories to the NPT, including the five NWS; all others are considered non-nuclear weapon states, of which are therefore 184. Not possessing nuclear weapons has become the norm, and promotion of a nuclear weapons free world is now globally accepted. What these nations do have, according to the terms of the NPT under Article IV, is the "inalienable right" to nuclear technology. This loophole has already been discussed and demonstrated by North Korea, but will other nations who are currently signatories to the NPT follow suit?

Is a "have not" who "could have" a would- be proliferator?

This question has plagued nuclear relations since the inception of the NPT, but never so much as current times with the expansion of civilian nuclear power[77] to many developing countries and one very prominent example of outright abuse of the "inalienable right" loophole and ability to withdraw from the NPT.

The biggest proliferation "threat" at the time of writing is Iran. The nuclear ambitions of Iran have been the subject of debate for over a decade with heightened suspicions since the 2006 announcement by Iranian President Mahmoud Ahmadinejad that Iranian centrifuge equipment had led to the successful enrichment to 3.5% of U-235 (Alam, 2011). Currently, the world tensely awaits the possibly of an Israeli pre-emptive strike on the nation. Bombing Iranian nuclear facilities, however, would only delay rather than prevent Iran getting the bomb if that is in fact their intention[78]. Iran signed the NPT in 1970, is an IAEA member and signed the Additional Protocol in 2003. Its nuclear program commenced in the 1950s under the Atoms for Peace programme and has advanced steadily since with Iranian nuclear infrastructure now reaching from uranium mining through to enrichment; however, IAEA reports dating back to 2004 repeatedly accuse the nation of non-compliance with safeguards obligations (Alam, 2011 p42). Tokhi (2010) finds that Iran adheres to only 25% of its recommended non-proliferation relevant agreements, but that compliance and

[74] http://www.economist.com/node/21542185
[75] http://www.economist.com/node/21548944
[76] http://www.economist.com/blogs/banyan/2012/04/north-koreas-sense-timing
[77] See Appendix C for a summary of the historical and forecast growth of nuclear energy in electricity generation.
[78] The Economist, 2011, February 25, Bombing Iran p 11.

commitment levels oscillate between high and low. It does seem as though the Islamic Nation is determined to achieve nuclear capabilities despite a great deal of international pressure to the contrary[79]. Why?

Security concerns have certainly played a significant role in Iran's nuclear ambitions. That the possibility of an Israeli pre-emptive strike on Iranian facilities is so widely debated at present highlights the veracity of this claim, and emphasises the existing hostility between the two nations. Alam (2011, p 40) makes the interesting point that the US use of force against Iraq in 2003 (which did not have nuclear weapons) contrasted with the absence of force used against North Korea (whose nuclear program has resulted in two testing events) has convinced Iran that nuclear weapons are essential in restraining US military action. Domestically, nuclear weapons are generally thought to help the Islamic regime by refocussing the Iranian people away from their hardships and encouraging nationalistic (and anti-West) tendencies (Sherrill, 2012 p41), restoring national pride and respect to the diminished nation (Alam, 2011 p 41), and strengthening the regime. The prestige of mastering the nuclear fuel cycle almost makes that path attractive for the proud nation (Ottolenghi, 2010) but given their apparent commitment to nuclear beyond the virtual, it would seem that they want the coercive power of actually possessing the weapons (Sherrill, 2012 p44). The supply-side motivations of proliferation are not considered to apply here since Iran has faced so many hurdles in getting the technology; that the AQ Khan network has been implicated in Iran's acquisition of nuclear know-how supports the argument for demand-side explanations of Iran's nuclear pathway.

However, Iran maintains that its development of a nuclear industry is not a front for nuclear weapons development, and evidence to oppose this has been inconclusive. Action based on suspicions brings back memories of the US raid on Iraq's WMD which were never discovered.

But they actually don't have

In spite of all this doom and gloom, it is important to acknowledge that "the nuclear non-proliferation regime is actually one of history's greatest success stories" (Perkovich, 2006 p362) and although Israel, Pakistan and India refuse to sign the NPT, North Korea withdrew and Iran is possibly failing to comply, there are many, many nations who have abstained from nuclearising their military forces in return for access to civilian nuclear technology. As Kissinger once said, "the history of things that didn't happen has never been written", but it is certainly worth acknowledging the countries such as Japan, Germany, Canada, Australia, Norway, Sweden, Italy and the entire continents of South America and Africa are nuclear weapon free. If we consider the NPT regime as the lack of proliferation rather than the outcome of signatures on the Treaty, then the NPT regime can certainly be considered successful with only a very slight rise in the number of nuclear armed nations in over forty years. There have even been cases of nuclear reversal; these shall now be discussed.

The rare but respected cases of nuclear reversal

Nuclear reversal is defined as the "phenomenon in which states embark on a path leading to nuclear weapons acquisition but subsequently reverse course, though not necessarily abandoning altogether their nuclear ambitions" by Levite (2002/03, p299) in a persuasive article which claims that nuclear reversal is more common than generally thought. As evidence, Levite points to seventeen states who embarked on the path to nuclear weapons but gave up, and also four states which attained nuclear

[79] Pressure includes everything from diplomacy and economic sanctions to military threats.

weaponry but went on to renounce their arsenal. Indeed, these four cases shed some interesting light on the disarmament aspect of the non-proliferation regime.

South Africa

This is a very interesting case, being the only case to date in which an indigenous nuclear arsenal has been dismantled; complete nuclear reversal.

The pathway to South Africa's acquisition of nuclear weapons began in the late 1960s, culminating in PNEs and then the decision to weaponise in the 1970s. South Africa began building atomic bombs in 1979[80]; then in 1990-1991 it scrapped the six and half Hiroshima-type weapons which had been produced and became the first and only nation to date, to undergo complete nuclear disarmament. The reasons for South Africa's nuclear acquisition are widely cited as more a result of the domestic politics than security concerns[81], but as in all other proliferation cases the explanation is complex and ambiguous.

This special case does allow for the otherwise hypothetical discussion as to what motivates states to dismantle their nuclear programmes. Liberman (2001) argues that although the security model can slightly account for the decision, domestic factors were the primary drivers in South Africa's 'dropping' of the bomb with a shift away from apartheid, and presidential leadership from de Klerk away from militarisation and toward liberalisation of the economy and society more generally.

The declassification of sensitive information and documentation can help policy makers, advisors and scholars alike understand the processes which led up to, and away from, decisions to include nuclear weapons in security strategies, and ultimately in the formation of global non-proliferation strategies. While much of the program remains shrouded in secrecy, documents which have been disclosed have shed light on covert histories, such as Israel's involvement in the South African program, when the government officially decided to acquire weapons, and what factors and events led up to the decision to disarm (see Harris et al., 2004). South Africa's decision to disarm has given it the prestige required to take a leadership role in NPT diplomacy (Harris et al., 2004 p471), and shown the world that nuclear rollback is a legitimate option.

The former Soviet States

Upon the disintegration of the Soviet Union in 1991, three of the former Soviet states inherited nuclear weapons which had been part of the nuclear stockpile built up by the Soviets in the arms race of the Cold War. Belarus, Kazakhstan and the Ukraine all chose to renounce nuclear weapons, although for different reasons. The Ukraine quickly moved to disarm in the face of domestic instability and threatening economic collapse; Kazakhstan utilised the weapons on their territory as bargaining chips in a variety of economic, environmental, and security needs; and the leader of Belarus seems to have had very little regard for nuclear weapons anyway (Potter, 2010 p74). These states were put in the unique position of essentially being born nuclear armed and thus did not need to "undo" any initial decision to acquire weapons. However, their ultimate decisions to relinquish the weapons iterate disarmament as a reasonable

[80] For a thorough discussion of South Africa's pathway to nuclearisation and decision to dismantle see Liberman, 2001.

[81] Harris et al., 2004 go so far as to report of suspicions that nuclear bombs may have even been built to use domestically against anti-apartheid revolutionaries p 473.

choice – a sentiment which is not, however, shared by the remaining nuclear armed states.

5. Conclusion: The Paradoxes of the Nuclear Environment

"We know that there is no text-book method on how to proliferate"
Müller and Schmidt p131

The delusion of disarmament

As has been outlined previously, Article VI of the Treaty undertakes each Party possessing nuclear weapons to pursue negotiations relating to nuclear disarmament. Rather than rolling back their nuclear programs, however, the NWSs have made significant advances in the field of atomic warfare, with the potency of nuclear weapons increasing markedly since WWII. Vertical proliferation has already been mentioned by way of the arms race during the Cold War; however the nature of the bomb has also became more sinister. Bigger and better weapons have been designed and tested since the dawning of the atomic era. A-bombs are relatively meagre when compared to H-bombs, or thermonuclear bombs. The US first tested a thermonuclear device in August 1953. It yielded ten megatons whereas the bomb dropped on Hiroshima yielded fifteen kilotons; a staggering difference, of which the dangers are told by the utter devastation reeked on the Japanese city. This huge increase in destructive power has played a role in both the trend toward non-proliferation and the affirmation of the nuclear bomb as the ultimate weapon. The four other declared nuclear powers followed suit at varying speeds; Israel is assumed but undeclared and India and Pakistan ostensibly aspire to such status. The destructive power of nuclear devices have been furthered by improvements in delivery technology: the development of intercontinental ballistic missiles make these weapons obviously more dangerous and the accuracy of missiles in general has been increased such that hitting the target is almost a given. The issue of these technologies is pertinent still today with a fairly constant crisis regarding North Korea's missile program, among others. These weaponisation technologies make issues of non-proliferation and disarmament more significant in global affairs as the consequences of nuclear usage are considered by many to be almost complete termination.

Until the time of Barack Obama's presidency, any talks of US disarmament have been oft mentioned, though largely rhetoric and it is probably not substantially different now. That no material progress has been made to this end essentially represents the NWSs failing to keep their side of the bargain, and threatens to undermine the spirit of the NPT regime which has otherwise seen proliferation limited to only the most determined outlaws, and delegitimize the original bargain opening up the door to future potential proliferators. If the nuclear weapons states refuse to disarm for the purpose of non-proliferation, then the non-nuclear weapon states may refuse non-proliferation. The "grand bargain" which has so successfully seen so few cases of proliferation may in fact provide motivation for states who feel the system is inequitable to pursue the nuclear option.

The links between disarmament and non-proliferation are unquestionable. There are no claims within the proliferation literature that in the complete absence of disarmament, non-proliferation will be successfully achieved. On the contrary, many claim that the two go hand-in-hand. Perkovich (1998, p20) claims that nuclear disarmament is the ultimate goal of non-proliferation if it is to succeed. Jankowitsch (2011, p2) claims "in essence, non-proliferation, arms control and disarmament are different approaches to the same objective: how to control and reduce nuclear

weapons, make them superfluous and thereby avoid nuclear catastrophe or, in the terse wording of Chapter VII of the UN Charter how to avoid "threats to peace …""
Harrington (2011, p5) makes the counterclaim that non-proliferation does not lead to disarmament, suggesting "the purpose of US non-proliferation policy is to obviate the need for the US to disarm itself." Furthermore, she argues that "non-proliferation is better understood as a strategy" driven by US statesmen rather than as a regime (p8) and draws commonalities between the "performative practices" (p11) of non-proliferation and the long adopted American policy of extended deterrence. Drawing on the credibility theory82 and recognising that "in so far as non-proliferation reduces nuclear danger, it also reduces the incentive to disarm" (p15) Harrington argues that:

> By behaving as if their pledge to disarm were credible, the nuclear weapon states continually renew their acknowledgement of the fundamental equality of all peoples while postponing its formal achievement. Whether or not any of these states actually believe in disarmament is irrelevant as long as they perceive it to be in their interests to act as if they do. (p18):

This is an insightful addition to the role, or lack thereof, of disarmament in non-proliferation and suggests that there may be little hope for any real advances toward eliminating nuclear weapons. Walker (2010, p448) points out that besides the obvious similarities of nuclear weapon possession, the nuclear-armed states are "marked more by difference than similarity" and thus "crossing the threshold into elimination would therefore be different and feel different for each state and region". Much like the road to nuclearisation, the journey in the opposite direction must be considered on a case by case basis.

Assessing the effectiveness of the NPT

From the discussions thus far regarding the motives behind nuclear weapon acquisition, and the explanations and theories relating to the general propensity of non-proliferation it is easy to imagine a set of global circumstances in which nuclear proliferation becomes exponentially prolific, and suddenly a plethora of nuclear armed, trigger happy nations emerge: imagining this scenario in the near future has been a constant theme since nuclear weapons burst into world affairs and proliferation became an urgent and significant matter of global policy. Given that nuclear weapons take a substantial length of time to develop83, and even the most determined proliferators have yet to demonstrate a willingness to use their weapons, worldwide Armageddon is an unlikely (although rather unfortunate!) outcome.

The success of the Non-proliferation Treaty is extremely difficult to measure. The very nature of the subject ensures it is shrouded with secrecy and many documents remain classified. What is undeniable is that far fewer states have acquired nuclear weapons than most commentators have forecast. Whether this is the result of the NPT is debatable, however it is significant to note that present conditions of the non-proliferation regime are unstable. With Iran still persisting with its nuclear program and Pakistan building up its nuclear arsenal at an impressive rate, disarmament seems like an impossible option. Without it the NPT regime threatens to unravel. These are interesting times and decisions made today may well determine whether a future arms race will develop in regions of the world.

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[82] Put forward by Christopher Ford, *Nuclear Disarmament, Non-proliferation and the Credibility Thesis* (Washington, DC: The Hudson Institute, September 2009), 2.
[83] Even for a country with all the technology and expertise it is estimated it would take at least six months.

As noted by Potter (2010, p69), although the challenges to the NPT are real and warrant both attention and action, it must be recognised that proliferation has been relatively slow and also "that proliferation is neither inevitable nor irreversible". He draws attention to the cases of nuclear reversal, the number of nuclear weapons programmes which have been abandoned before a weapon was actually produced, and the fact that the NPT is the most widely subscribed to international agreement in existence. This all points to the NPT regime having quantifiable merit. But, internal problems of NPT are inherent to the global regime, and will continue to put it under significant pressure.

Miller (2012, p21) has recently argued that "if 2010 was the year of successes and landmarks, 2011 was the year that the momentum of the new era slowed and hard realities resurfaced" and outlines five developments which shaped the year:

1. The nuclear order got wider with Abu Dhabi breaking ground on the first of four nuclear reactors, the Iranian reactor at Bushehr began operating and was connected to the power grid, and construction of a Russian plant began in Vietnam

2. Export controls got tighter with the cartel formed in the Nuclear Suppliers Group, which now consists of 46 member states, agreeing to firmer regulation and supplemental safeguards to those formalised by the IAEA.

3. Iran... US engagement seems to have diminished and the problem looks set to burn on into 2012

4. The Middle East conference moved forward with a Finnish facilitator engaged for the job, however it will be a long road to the desired Middle East establishment of a WMD free zone with the participation of the primary targets, Iran and Israel, yet to be confirmed.

5. US-Russian relations sputter, with the momentum of the 2010 New START agreement diluted by differences over missile defence programs, making further arms control and reduction measures a distant hope.

These are all current issues which must be considered in looking forward and working toward a nuclear weapon free world in a world with significant energy demands of which nuclear power can play a part. Solingen (2012, p297) claims that "few topics are as critical to peace and international security as is nuclear proliferation" which iterates the significance of getting these issues right.

Weapons proliferation and nuclear economics

With claims such as "although there may be reasons to use reactors to address climate change, economics does not appear to be one of them" (Shrader-Frechette, 2011 p75) the role of proliferation in state level decisions to invest in nuclear energy must be considered. This paper has assumed the purported benefits of nuclear energy84 and noted the risks before launching into an in depth examination of the issue of weapons proliferation, which has undoubtedly been far less extensive than has been historically

[84] See Appendix C for more on the economics of nuclear energy.

forecast. Like the proliferation of weapons, the spread of nuclear energy applications has been significantly lower than its original proponents imagined.
That Struass' prediction of "electrical energy too cheap to meter"[85] has not eventuated is evidenced by the fact that nuclear energy makes up only 13.5% of world electricity generation today; a number which has actually been declining since it peaked at 17.68% in 1996. The debate regarding nuclear electricity generation remains open and is relevant to the issue of proliferation given the dual-purpose of much of the technology as has already been mentioned.

Given the lack of clarity in states' decisions to invest in nuclear energy, the role of proliferation in such decisions becomes particularly pertinent, and underscores the NPT "loophole" through which states can legitimately begin weapons programs via the introduction of civilian nuclear power. After all, the world's first nuclear program built a bomb not a power station. The cost of a weapons program is greater than that of a civilian program with far fewer tangible benefits, and some other notable costs. For example, sanctions against Iran's nuclear ambitions "appear to have led to a substantial deterioration of the Iranian economy" (Nader, 2012 p211). Costs imposed on North Korea in an attempt to curtail its program were passed onto its citizens by the regime "even to the extent of allowing recurrent food shortages" (Haggard and Noland, 2012 p259).

While the economics of nuclear energy may be debatable[86], it would seem that the costs of weaponising such technology imposed by global trading partners should make such programs inconceivable. This has not been the case, however, suggesting that economic arguments are irrelevant in cases of determined proliferators.

Final remarks

There are many aspects of the nuclear industry which are highly appealing: nuclear energy offers a low carbon alternative to fossil fuel derived electricity, nuclear power is less susceptible to volatilities in commodity markets thereby making its running costs more predictable, fuel for nuclear reactors can be effectively stored in advance, and all of these factors help bolster the energy security of the state with the technology. However, these benefits come with a number of physical risks, as evidenced most emphatically by the ongoing drama in Japan resulting from the Fukushima disaster in 2011, as well as the risk of proliferating nuclear weapons. The motives for countries pursuing bomb acquisition have been discussed, and the point which has been made most clear is that there is seemingly no one 'best' explanation for such trajectories. Rather, nations may pursue nuclear arsenal for one or more of many reasons and these reasons may change over time. Adding to this paradox of nuclear expansion is the alleged stability which nuclear weapons have brought to global relations, most notably during the period of the Cold War. Such arguments for nuclear optimism add to the confusion which surrounds the world's nuclear future.

Nuclear proliferation is undoubtedly much more than a mere security response. If faced against an enemy such as the United States, with 5,000 nuclear warheads at its disposal (having been significantly reduced) and assuming its technical capacity to increase this number rapidly, a nation such as Iran – with less than one quarter of the population and GDP less than 2% of the US – would be ambitious, to say the least, in thinking developing a weapons program would prevent it being extinguished by such a large enemy should the occasion arise. On the other hand, it would grant it the capability to wipe out Israel – a feat which would be equally as likely to render utter

[85] http://en.wikipedia.org/wiki/Too_cheap_to_meter
[86] See Appendix C.

desolation on itself. The irony is that the closer Iran gets to its own bomb, the closer Israel comes to using theirs.
Domestic actors ultimately make decisions regarding nuclear programs, and thus the role of domestic politics in proliferation is inextricable. Key players, be it the state leader, strong bureaucracies or determined militaries, are all vital to the development, management and resourcing of nuclear programs. The accomplishment of nuclear prowess brings with it a great deal of power and prestige; being almost as technically challenging as a weapons program, the establishment of a civilian program brings similar accolades, proving to world that big science is not only the domain of the rich and powerful. For those developed nations with existing civilian nuclear programs, the comfort of 'virtual' access to nuclear weaponry may enable them to forge ahead with the US driven (but very poorly demonstrated) quest to prevent the spread of nuclear weapons.

Nuclear proliferation, and indeed nuclear power, are emotionally charged topics which immediately bring to mind the worst science has to offer – Hiroshima, Fukushima, Chernobyl. While these are very serious accidents/events, the United States has intentionally let off 1,030 nuclear "explosions" in various parts of the world, honing its tactical nuclear capabilities; Russia a further 715, France 210, and the UK and China 45 each87. At times it seems as though the US is simultaneously the biggest driver behind non-proliferation, whilst also being its greatest inhibitor via its resistance to disarmament.

The proliferation of nuclear technology as a means of generating electricity is set to continue. Although open to debate, the economics of nuclear power is only set to improve as heavy polluters start to pay for the environmental costs which have otherwise been ignored. Even if the world keep using coal and gas for as long as it can, if the climate change advocates are right, our successors are going to need some seriously clean energy and lacking any momentous innovations, nuclear will be (at least part of) the answer. Given that the only probabilistically likely argument against nuclear power is its cost, perhaps the world should be embracing it today – allowing that the climate-changers may be right.

[87] Not to be forgotten: India 3, Pakistan 2, and North Korea 2.
http://www.armscontrol.org/factsheets/nucleartesttally

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Appendices

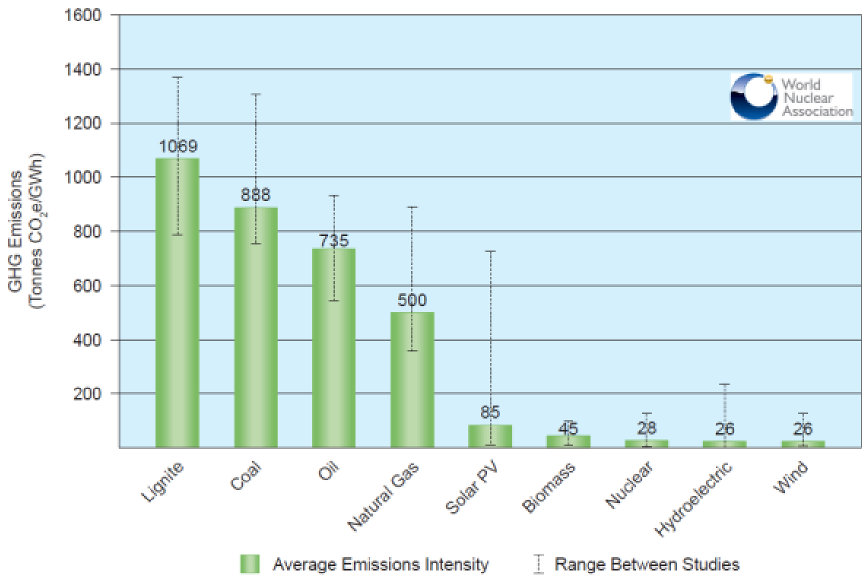
A. Greenhouse Gas Emissions of Various Methods of Electricity Production

WNA has published a new report reviewing over twenty studies of greenhouse gas emissions from electricity generation. The report concludes that the third party studies clearly show that greenhouse gas emissions from all forms of fossil fuel generation are an order of magnitude higher than those from nuclear energy and renewables.

Although there are variations between studies of the emissions associated with different forms of generation, by taking a mean value the following conclusions can be made:

- Greenhouse gas emissions of nuclear power plants are among the lowest of any electricity generation method and on a lifecycle basis are comparable to wind, hydro-electricity and biomass.
- Lifecycle emissions of natural gas generation are 15 times greater than nuclear.
- Lifecycle emissions of coal generation are 30 times greater than nuclear.
- There is strong agreement in the published studies on life cycle GHG intensities for each generation method.

Figure A1. GHG emissions of different methods of electricity production
Source: http://www.world-nuclear.org/wnaupdate/lifecyclegreehousegasemissionsreport.html



B. Cost Comparisons of Electricity Generation

The IEA/NEA 2010 report 'Projected Costs of Generating Electricity' found:

> nuclear, coal, gas and, where local conditions are favourable, hydro and wind, are now fairly competitive generation technologies for baseload power generation. Their precise cost competitiveness depends more than anything on the local characteristics of each particular market and their associated cost of financing, as well as CO_2 and fossil fuel prices… There is no technology that has a clear overall advantage globally or even regionally. (p21)

To exemplify this statement, two figures from this report have been reproduced, Figure ES.1 and Figure ES.2. The graphs show ranges of LCOE for nuclear, coal, gas and onshore wind power plants by region; those shown are for North America, Europe and Asia Pacific and the countries included in the data are shown down the vertical axis. The first figure uses a discount rate of 5%, the second 10%. The variation is staggering; however in all cases except Europe at a 10% discount rate, the median LCOE for nuclear is lower than coal, gas and wind.

As noted in the discussion of nuclear economics, industry reports may suffer from a conflict of interest and thus offer swayed results (Shrader-Frechette, 2011). However, from the very same report the World Coal Assoication proudly claims that coal power plants provide electricity at much lower cost than gas or nuclear plants, and this advantage is even greater compared to renewable energy. Table B1 has been taken straight from the World Coal website.

Table B1. Comparison of Electricity Generation Costs - International Studies (US$)

Source: taken from World Coal Association

	US Congressional Budget Office 2008	European Commission 2008	EPRI 2008	House of Lords 2008	MIT 2009	Average Cost
Coal	56	59	64	82	62	65
Gas	58	72	80	78	65	70
Nuclear	73	87	73	90	84	81
Biomass	n/a	180	80	180	n/a	145

Source: IEA, Projected Costs of Generating Electricity, 2010
http://www.worldcoal.org/resources/ecoal/ecoal-current-issue/costs-of-coal-fired-electricity/

Figure ES.1: Regional ranges of LCOE for nuclear, coal, gas and onshore wind power plants
(at 5% discount rate)

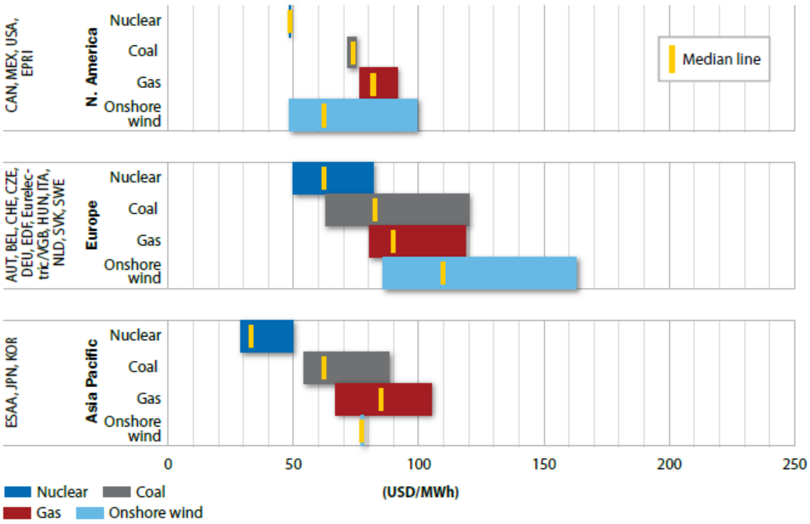
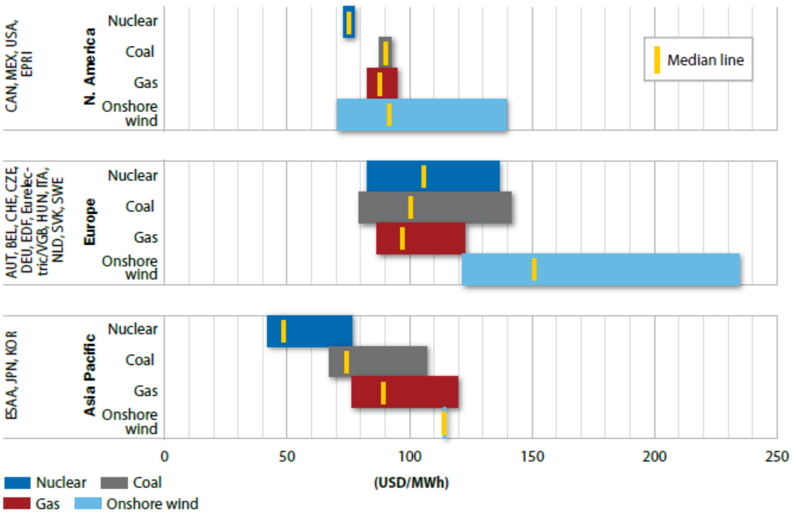


Figure ES.2: Regional ranges of LCOE for nuclear, coal, gas and onshore wind power plants
(at 10% discount rate)



This all seems to surmount to a rather confusing scenario, partly which can be explained by the differences in cost structures between the technologies. The IEA/NEA report provides a summary of the relative weight of each cost component at a 5% and 10% discount rate. This has been shown below as Table B2; note the high investment cost of nuclear, and changing the discount rate from 5 to 10 increases this dramatically.

Table B2. Total generation cost structure

Source: IEA/NEA 2010 p112

	at 5%						at 10%					
	Nuclear	Coal	Coal w/CCS	Gas	Wind	Solar	Nuclear	Coal	Coal w/CCS	Gas	Wind	Solar
Total Investment cost	58.6%	25.9%	51.6%	11.1%	76.5%	91.7%	75.6%	39.8%	66.8%	17.3%	83.8%	94.9%
O&M	25.2%	9.2%	21.9%	5.2%	22.7%	7.3%	14.9%	7.5%	15.1%	4.9%	16.0%	4.9%
Fuel costs*	16.0%	27.9%	21.0%	71.3%	0.0%	0.0%	9.5%	22.8%	14.5%	66.4%	0.0%	0.0%
CO_2 costs	0.0%	36.8%	5.2%	12.3%	0.0%	0.0%	0.0%	29.9%	3.6%	11.4%	0.0%	0.0%
Decommissioning	0.3%	0.1%	0.2%	0.1%	0.8%	1.0%	0.0%	0.0%	0.0%	0.0%	0.2%	0.3%

*Fuel costs for nuclear comprise the costs of the full nuclear fuel cycle including spent fuel reprocessing or disposal.

The qualitative advantages and disadvantages of various methods of electricity generation have been summarised in Table B3, while a summary and qualitative assessment of the risks of each generating technology has been presented in Table B4.

Table B3. Source: IEA/NEA 2010 p21-23

Method of Generation	Advantages	Disadvantages
Nuclear	Capability to deliver significant amounts of very low carbon baseload electricity at costs stable over time	High amounts of capital at risk and long construction time Radioactive waste and safety Nuclear security and proliferation
Coal	Economic competitiveness in the absence of carbon pricing and neglecting other environmental costs	Transport costs of plant is far from mine Probability of carbon and environmental costs to be paid
Carbon capture	Has not yet been commercially demonstrated and thus costs remain uncertain	
Gas-fired	Flexibility Ability to set price in competitive markets, hedging financial risk Lower CO_2 profile	High cost given gas price assumptions Security of supply
Onshore wind	Closing its existing (but diminishing)competitiveness gap	Variability and unpredictability can make system costs higher

Technology	Unit size	Lead time	Capital cost/kW	Operating cost	Fuel cost	CO_2 emissions	Regulatory risk
Gas	Medium	Short	Low	Low	High	Medium	Low
Coal	Large	Long	High	Low	Medium	High	High
Nuclear	Very large	Long	High	Medium	Low	Nil	High
Hydro	Very large	Long	Very high	Very low	Nil	Nil	High
Wind	Small	Short	High	Medium	Nil	Nil	Medium

Table B4.

Source: IEA/NEA 2010 p172

Note: CO_2 emissions refer to emissions during combustion / reformation only.

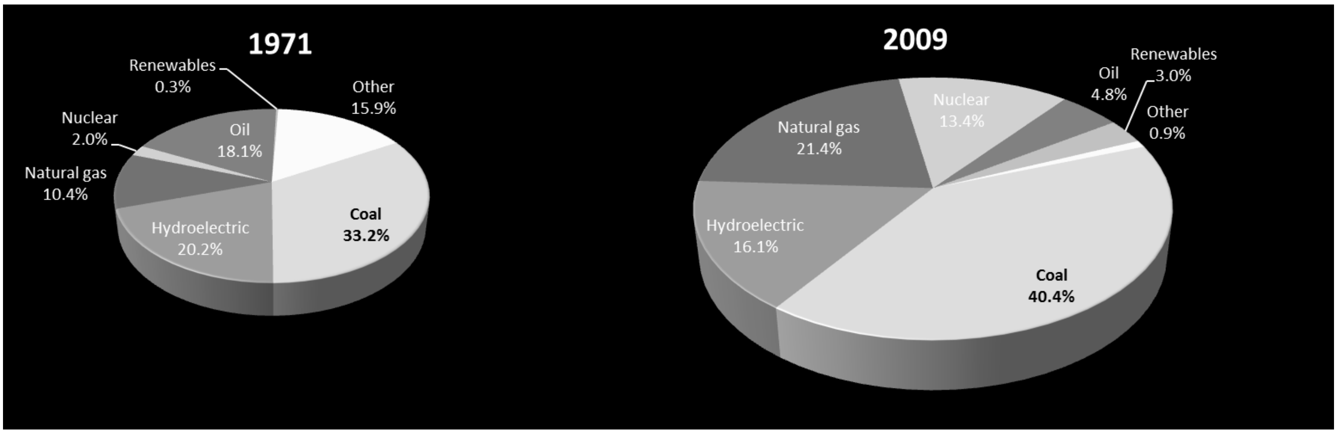
C. Nuclear Power….. Economic?

An overview of nuclear energy within the global energy sector shall now be provided. This part of the study does not seek to prove or disprove the economics of nuclear energy; rather the contentious nature of nuclear programs will be highlighted and the sources of such uncertainty identified.

Nuclear energy: past and present

The first commercial nuclear power stations started operation in the 1950s and with the promise of clean, cheap energy the technology, spread throughout the developed world increasing in both total and relative capacity. Figure C1 illustrates the change in nuclear electricity generation relative to other fuels from 1971 to 2009 over which time world total electricity production rose from 5,234 to 20,079 TWh while nuclear grew from 105 to 2,696 TWh[88].

Figure C1. World electricity generation by source, 1971 vs. 2009
Data source: World Bank

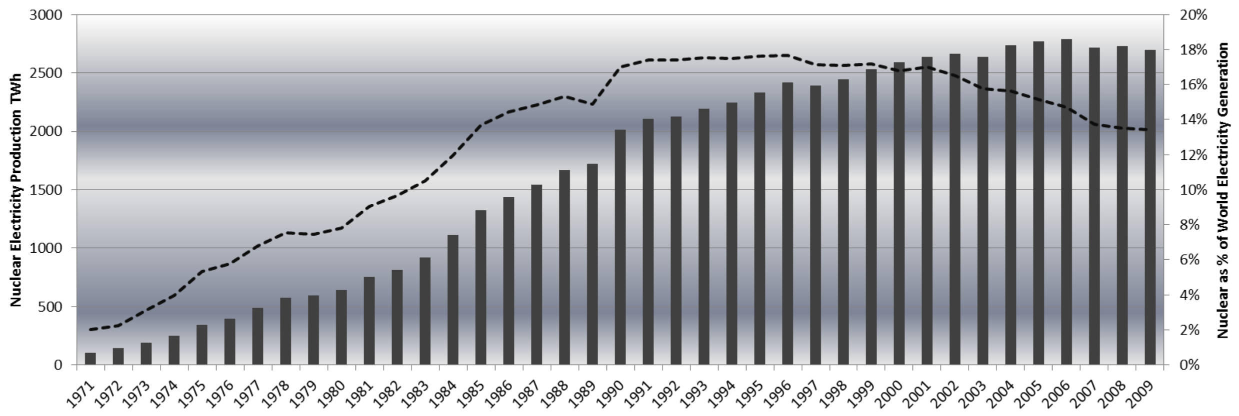


Nuclear makes up a small but significant part of the global energy market. Energy is fundamental to the world as we know it. Although when measured in terms of GDP, energy resources represent around only 5% of economic output, the other 95% depends entirely on energy inputs (Harris, 2006 p279). Nuclear energy is primarily utilised in the generation of electricity; in addition a further 180 reactors power some 150 ships and submarines and 240 research reactors operate worldwide[89].

[88] World dataBank World Development Indicators and Global Development Finance http://databank.worldbank.org
[89] http://www.world-nuclear.org/info.inf01.html accessed 4/5/2012

Figure C2. Global nuclear electricity production 1971-2009: absolute and relative

Data source: World Bank



As already mentioned, nuclear generating capacity has been decreasing relatively and also slightly in total capacity also. Figure C2 shows the year by year data of total nuclear electricity production and nuclear's share of electricity production, highlighting a marked decline in growth over the past decade and a notable loss of overall share. This trend warrants further consideration, but for now can explained by the boom of new construction of new plants in the 1970s and 80s, as depicted in Figure C3 which shows worldwide construction of nuclear reactors over time. As these reactors reach retirement age and go offline, the rate of new build has not kept pace.

Figure C3. Nuclear reactors under construction worldwide

Source: Davis, 2012 p52

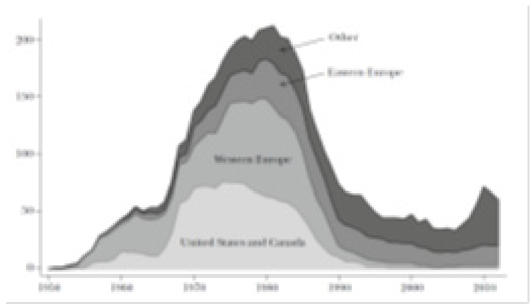
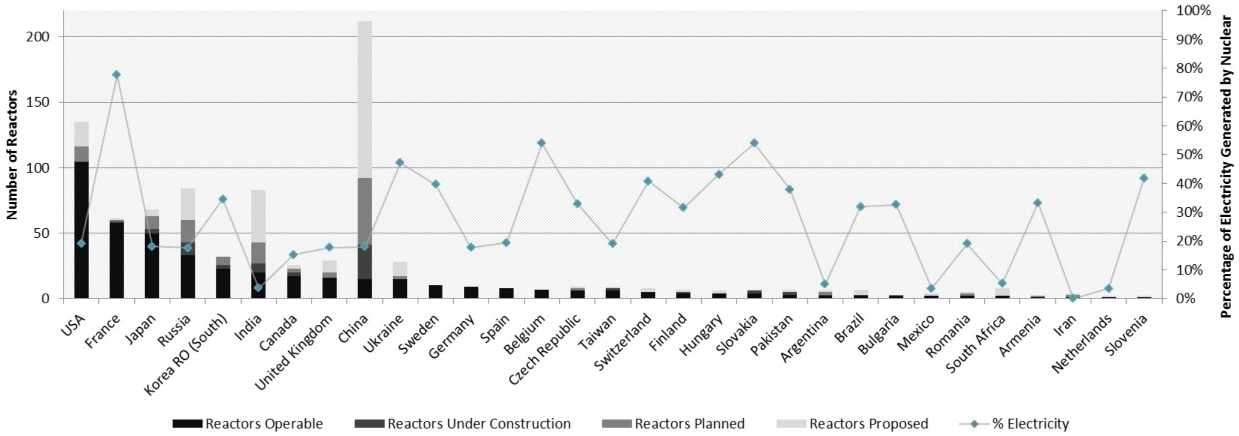


Figure C4 depicts the 31 countries which currently have together 433 operating nuclear power plants providing 372,000 MWe of total capacity, as well as the overall share of nuclear power in electricity generation for each state. Although the US has the most reactors at 104, France produces 77.7% of its electricity using nuclear energy. Reactors under construction, planned and proposed for those state's with existing nuclear facilities has been included in the figure, highlighting the stagnation in nuclear developments with the exceptions of China, India and Russia.

Figure C4. Reactors Operating, Under Construction, Planned and Proposed for Countries with Existing Nuclear Power Facilities

Data source: WN



With an overview of the current position of nuclear energy in the global market, let us quickly revisit the drivers and constraints of nuclear energy which were covered in the first section of this paper before looking forward into the future of nuclear energy. These have been summarised in the Table C1 for convenience.

Table C1. Drivers and constraints of nuclear energy

Drivers	Constraints
• Increasing demand for energy, particularly electricity • Climate change and the push for low-carbon energy generation • Energy security and less exposure to volatility in commodity markets • Economics, especially if carbon prices increase • Technology improvements in nuclear power facilities leading to improved efficiencies • Prestige and modernity symbolised through such accomplishments • Aggressive marketing of the technology	• Technical risks associated with the reactor itself eg. Chernobyl and Fukushima • The problem of spent fuel: storage and disposal • The huge capital costs of such projects presents quite a hurdle and long timeframe introduces finance risks • Proliferation concerns • Public opinion, although the result of the above risks, becomes its own mammoth hurdle with active resistance to projects • Industry bottlenecks and technical shortages with a diminishing industry

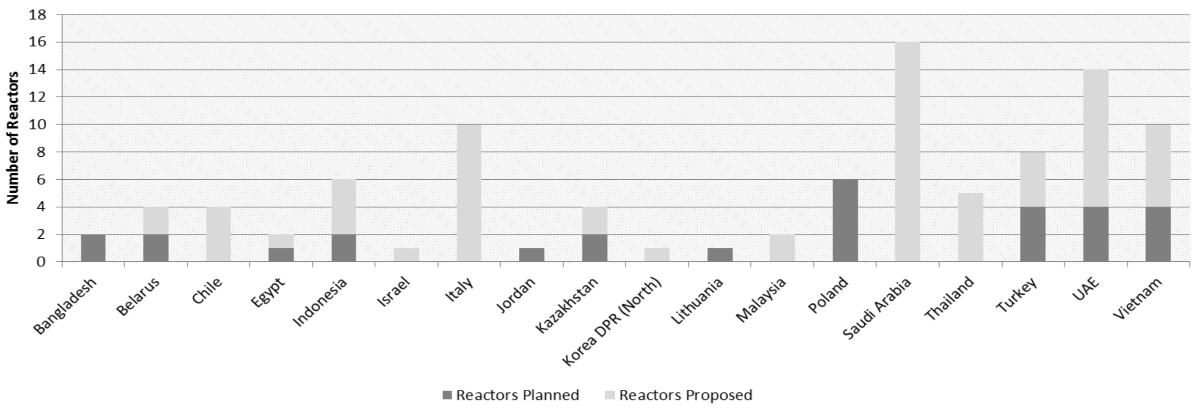
Forecasting nuclear growth

Growth estimates vary hugely, depending substantially on the role of carbon considerations in forecasts. In making future estimates, the IEA differentiates between the Reference Scenario, whereby it's business as usual and climate change concerns are largely ignored, and the 450 Scenario, an extremely unlikely outcome whereby greenhouse gases are limited to a concentration equivalent to 450ppm of CO_2 equivalent which is roughly consistent with a temperature rise of no more than 2 degrees by the end of the century[90]. The latter Scenario calls for an extra $125 billion investment in 36 GW of nuclear capacity above the former for the period 2010-2020 and a further $491billion for an extra 143GW capacity in the period 2021-2030 for a total of almost $1,300 billion investment for the 20 year period (WEO, 2009 p7,266). IAEA (2011, p17) estimates range from 3,946 to 5,878 TWh in 2030 and 4,513 to 9,893 TWh in 2050 representing a maximum share of 14.0% and 13.5% respectively in electricity generation and contribution.

The projected growth of nuclear energy includes the adoption of the technology by a number of countries without existing nuclear facilities. Figure C5 shows proposed and planned reactors for these 18 countries, totalling 29 planned reactors and a further 68 proposed.

Figure C5. Reactors Planned and Proposed for Countries without Exisiting Nuclear Facilities

Data source: WNA



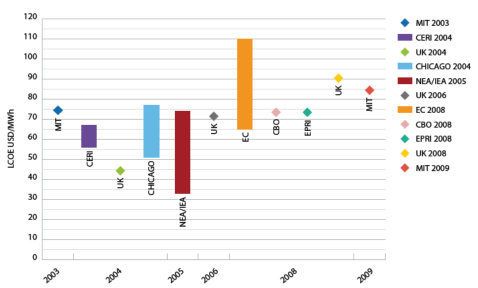
Identifying the unknown

1. Plant costs: how big is big?

This paper has consistently referred to the ‘huge’ costs of both civilian and military nuclear programs, but has thus far paid little attention to what these costs actually are. So, how big is big? For the sake of a little perspective, the economics of nuclear programs in real terms shall now be explored in more detail. At the heart of the economic debate regarding nuclear energy is the variance of pricing. Figure C6 shows the levelised cost of electricity (LCOE) for nuclear power plants from a number of different studies. The results range from 33 to 110 USD/MWh; this is in contrast with coal (27-75), IGCC (42-72) and gas (38-82). Given the indeterminate nature of pricing it is no wonder that comparisons can be hard to make!

Figure C6. Cross-study comparison of LCOEs for nuclear plants

Source: IEA/NEA Projected Costs of Generating Electricity 2010 p196



The trouble here stems from the

[90] http://www.iea.org/speech/2009/Jones/GECE09.pdf

differences in cost structures; nuclear plants are expensive to build and cheap to run whereas fossil fuel plants are cheap to build and expensive to run[91]. "Overnight" construction costs are typically used when evaluating capital costs omitting financing costs, which can contribute enormously to the actual cost of a plant.

Shrader-Frechette (2011) assesses 30 prominent, international, nuclear-cost studies, all of which are original economic analyses rather than summaries. She finds the majority of studies appear to trim nuclear-cost data in at least three ways, iterating the controversial costings of nuclear power:

1. Ignoring taxpayer subsidies which cover many costs of nuclear generated electricity including insurance, a significant cost given the potential liability involved.

2. Using "overnight" plant-construction-capital costs assumes 0 interest rate and 0 construction-times when in fact including interest rates for the 10+ years taken to build a plant will increase capital costs by 200% and operating costs by 150% (p79-80).

3. Overestimating reactor lifetimes and nuclear-load or capacity factors; many reports predict a capacity factor of 85% or better when in fact a load figure of only 71 or 79% is achievable given historical averages.

To return to the question of how big is big…? Davis (2012, p57) claims that a typical two-reactor 2,000 megawatt plant could cost more than $12 billion including finance. This is a figure larger than the GDP of many countries, and a significant portion of even fairly wealthy countries; some claim a country with a GDP of less than $50 billion could not build a nuclear power plant (Banks and Ebinger, 2011 p2). Whether or not the plant is cheap to run is irrelevant if that amount of capital is unattainable. The scale of such projects also prohibits private investment, leaving nuclear programs largely in the domain of governments who may be swayed one way or the other for reasons other than economics. Given the lack of recent construction experience in new nuclear plants, accurate costing is made more difficult due to supply chain difficulties and the extra expenses always involved in first-build projects. What's more, Ferguson (2011, p70) points out "the financial challenges of building and operating a nuclear power plant depend on where it is located" and goes on cite cash reserves, government control over electricity generation, government financing, federal loan guarantees, mergers, regulatory incentives and the cost of fossil alternatives as factors which effect the competitiveness of nuclear power.

Adding fuel to fire, a 2007 European Commission study into nuclear power and sustainability found in favour of nuclear power, but that the reprocessing of spent fuel and fast neutron reactor would be required (cited in Ferguson, 2011 p163). The creation of a plutonium economy would enhance proliferation risks to what many would call and unacceptable level.

Ultimately, the jury does not look to be heading toward consensus anytime soon on the economics of nuclear power. What is generally agreed upon, however, is that the cost of fossil fuel alternatives will go up leaving nuclear to take a stronghold over its capital costs and be competitive. This leads us nicely into the next point of discussion

[91] See Appendix B.

which is necessarily related, but not always a feature of technical economic analyses given inherent conflicts of interest: the costs of the uncosted.

2. Environmental costing and externalities

The WNA claims "if the social, health and environmental costs of fossil fuels are also taken into account, the economics of nuclear power are outstanding"[92]. A recent study by Muller, Mendelsohn and Nordhaus (2011) presents a framework for the integration of external damages into national economic accounts. Although nuclear energy is not featured in this study, some startling revelations are made regarding its fossil fuel burning competitor, the coal-fired plant. Asserting that emissions should be valued by the damage they cause, the authors calculate gross external damages (GED) from air pollution caused by various industries and go on to also include ratio to value added (VA). Among their findings, they report that not including CO_2 [93], coal-fired electric power generators produce the largest GED of $53 billion annually, contributing over one quarter of GED from the entire US economy and totalling more than the combined GED due to the next three polluting industries (p1667). Furthermore, including climate-change effects from CO_2 increases damages by 30-40% using a conservative social cost of carbon estimate. Either way, the GED/VA ratio is 2.20 at minimum, meaning the damages are over twice the value added. The authors find coal-fired facilities to have the highest GED/kWh[94] at 2.8 cents.

The legitimacy of climate change is certainly a matter outside the scope of this paper; however it is interesting to note that a number of prominent environmentalists have done a complete about face on their original objections toward nuclear energy. Controversial environmentalist Patrick Moore, one of the founding members of Greenpeace, proclaimed in 2006, "Nuclear energy is the only large-scale, cost-effective energy source that can reduce these emissions while continuing to satisfy a growing demand for power. And these days it can do so safely.[95]" This statement was, of course, pre-Fukushima, however Moore's continued support reflects a growing acceptance of nuclear's ability to play a role in reducing greenhouse gases. Jonathan Lash, environmentalist and former President of the World Resources Institute coined nuclear a "necessary evil" in combatting climate change during his reign. James Lovelock, a scientist, environmentalist, inventor and author, sees nuclear power as not only necessary but a natural part of the solution to the climate change problem. Of course, not all environmentalists have adopted this position: Lester Brown, President of the Earth Policy Institute maintains "nuclear power is uneconomical"[96] and highlights the risk of catastrophic accident.

Nuclear considerations aside, it is most certainly true that economic costs have been severely underreported in energy economics.

3. Subsidising energy

Ferguson (2011, p70) makes the point that "for better or worse, producers of every energy source have received subsidies and financial incentives, such as federal tax credits for the generation of renewable energy and tax deductions for the costs of oil exploration and building refining facilities". Inclusion of this point is to highlight the market distortions caused by subsidies of various energy sources by various countries, further clouding the debate regarding the economics of nuclear energy.

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[92] http://www.world-nuclear.org/info/inf02.html
[93] CO_2 has been separated due to the particularly nasty health damages of SO_2, particulate matter, NO_x, VOC and NH_3
[94] Higher than oil-fired (2c GED/kWh) and natural gas (0.1c GED/kWh)
[95] http://www.washingtonpost.com/wp-dyn/content/article/2006/04/14/AR2006041401209.html
[96] http://www.earth-policy.org/plan_b_updates/2008/update78

The global energy sector is claimed to receive over US$240 billion in subsidies[97] annually in a review of subsides for electricity-generating technologies by Badcock and Lenzen (2010, p5038). The authors find that both the financial subsidies and the external costs of coal-fired power "dwarf those of all other technologies" (p5044). The WNA claims that "nowhere in the world is nuclear power subsidised per unit of production", and in fact is taxed in some countries due to low production costs[98]. And furthermore, that "today, apart from Japan and France, there is about twice as much R and D investment in renewables than nuclear, but with rather less to show for it and with less potential for electricity supply".

Which energy supplies governments choose to subsidise into the future, if in fact any, will continue to play a significant role in any comparisons of electricity generating methods.

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[97] Subsidies consist of financial subsidies, R and D funding, and externalities not accounted for in pricing system.

[98] http://www.world-nuclear.org/info/inf68.html accessed 26/4/2012.